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Research Paper

Piezoelectric Road at Toll Plaza-2

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ABSTRACT The proposed project, “Piezoelectric Road at Toll Plaza”, is an innovative smart-road system designed to generate electrical energy from the mechanical pressure produced by moving vehicles. In this system, piezoelectric plates are installed beneath the road surface at the toll plaza. Whenever a vehicle passes over these plates, the applied mechanical pressure is converted into electrical energy through the piezoelectric effect. The generated electrical energy is collected, stored and monitored through an electronic control system. A mobile-based monitoring system is also proposed to display the amount of electricity generated by the vehicles in real time. Along with energy generation, the system can automatically detect and record the number of vehicles crossing the piezoelectric road. This information can be transmitted to the mobile application, allowing the user to monitor both vehicle count and electricity generation from the toll plaza remotely. The proposed system combines renewable energy generation, smart transportation monitoring and IoT-based data communication. It can help utilize the continuous movement of vehicles at toll plazas as a potential source of electrical energy while providing useful traffic and energy data. The project demonstrates the potential of integrating piezoelectric technology with smart-road infrastructure for sustainable and intelligent transportation systems.

Construction of a Piezoelectric Road

A practical piezoelectric road can contain several layers and components.

Pavement Layer

The upper pavement layer carries vehicle traffic and transfers a portion of the mechanical load toward the energy-harvesting devices.

Piezoelectric Transducer

The transducer is the central component. It converts mechanical stress or deformation into electrical energy.

Possible configurations include:

- Piezoelectric ceramic elements
- Cymbal-type transducers
- Piezoelectric stacks
- Cantilever-beam harvesters
- Piezoelectric composites

- Flexible piezoelectric films

Protective Housing

Because road environments are exposed to water, dust, temperature variations, vibration, impact, and repeated loading, piezoelectric elements require mechanical and environmental protection.

Protective packaging is therefore an important area of roadway piezoelectric research.

Electrical Circuit

The raw electrical output from piezoelectric elements is generally unsuitable for direct use. A conditioning system is required.

Typical components include:

- Rectifier
- Voltage regulator
- DC/DC converter
- Impedance-matching circuit
- Energy-storage device
- Control circuit

Energy Storage

Because vehicle traffic is intermittent and the electrical output varies with vehicle loading, energy storage is useful.

Possible storage devices include:

- Rechargeable batteries
- Supercapacitors
- Hybrid battery-supercapacitor systems

Piezoelectric Materials

Different piezoelectric materials have different electrical, mechanical, thermal, and durability characteristics.

PZT

Lead Zirconate Titanate (PZT) is one of the most widely investigated piezoelectric ceramics.

Advantages include:

- High piezoelectric response
- High electromechanical coupling
- Good energy-conversion capability
- Extensive research history

However, PZT is relatively rigid and brittle. It therefore requires suitable mechanical protection when subjected to repeated roadway loading. Recent roadway research continues to investigate structural designs that can protect and efficiently load PZT elements. Sage Journals

PVDF

Polyvinylidene fluoride (PVDF) is a flexible piezoelectric polymer.

Advantages include:

- Flexibility
- Low weight
- Good chemical resistance
- Ability to tolerate relatively large deformation
- Potential suitability for flexible pavement-integrated systems

Its piezoelectric response is generally lower than that of PZT, so there is a trade-off between flexibility and electrical output. Sage Journals

Piezoelectric Composites

Composite materials combine piezoelectric materials with other structural materials. They can potentially provide a better balance between mechanical durability and electrical performance.
Research into composite and structural designs is important because a roadway harvester must simultaneously survive repeated traffic loading and produce useful electrical energy.

Working of a Piezoelectric Road

The operation can be explained in the following steps.
Step 1: Vehicle approaches the harvesting section
A vehicle travels over the section of pavement containing piezoelectric transducers.
Step 2: Mechanical load is applied
The weight of the vehicle generates stress and deformation in the pavement.
Step 3: Stress reaches the transducer
The pavement structure transfers an appropriate portion of the load to the piezoelectric element.
Step 4: Electrical charge is generated
The piezoelectric material produces an electrical response as a result of mechanical deformation.
Step 5: Electrical output is collected
Multiple transducers can be electrically connected in suitable series/parallel configurations.
Step 6: Rectification occurs
Because the generated signal may be alternating or polarity-changing, a rectifier can convert it into a suitable DC form.
Step 7: Voltage and current are regulated
A power-management circuit conditions the electrical energy.
Step 8: Energy is stored
The conditioned energy can be stored in a battery or supercapacitor.
Step 9: Electricity is used
The stored electricity can supply sensors, communication devices, warning systems, LED lighting, and other low-power applications.

Discussion

Piezoelectric road technology represents an innovative connection between civil engineering, electrical engineering, materials science, and renewable energy.
Its most important advantage is the direct relationship between the energy source and the transportation infrastructure. Vehicles already impose mechanical loading on roads, and piezoelectric technology provides a method for recovering a portion of this energy.
However, the technology should be viewed realistically. A piezoelectric road should not necessarily be expected to replace conventional electricity generation for large-scale applications. Current evidence more strongly supports its use for localized, low-power transportation applications such as sensors, communication nodes, monitoring equipment, and selected lighting systems. This conclusion is consistent with recent reviews emphasizing the promise of the technology while identifying output, cost, durability, and economic evaluation as major barriers.
The most promising future approach may therefore be a **smart hybrid road**, where piezoelectric energy harvesting is combined with solar generation, energy storage, wireless sensors, traffic monitoring, and intelligent control.

Conclusion

Piezoelectric road technology is an emerging approach for harvesting mechanical energy generated by road traffic. By embedding piezoelectric transducers into pavement structures, mechanical stress caused by passing vehicles can be converted into electrical energy.

The technology has several advantages, including local renewable-energy generation, compact installation, compatibility with smart-road systems, and the possibility of powering autonomous sensors. PZT, PVDF, and piezoelectric composites are among the important materials investigated for roadway applications.

Nevertheless, large-scale implementation faces significant challenges. These include installation cost, limited and variable power output, mechanical fatigue, environmental protection, electrical losses, maintenance, and uncertain long-term economic performance. Research has demonstrated technical feasibility, but laboratory output cannot automatically be assumed to represent full-scale road performance.

Therefore, the most realistic near-term application of piezoelectric roads is as a **supplementary energy source for low-power intelligent transportation infrastructure**. Continued research in materials, structural design, protective packaging, power electronics, energy storage, and field testing can improve the feasibility of the technology. In the long term, integration of piezoelectric harvesting with other renewable-energy technologies could contribute to the development of sustainable and intelligent transportation infrastructure.

References

AI and machine-learning methods could analyze traffic and pavement data to predict energy production and optimize the operation of smart-road systems.

1. Mou, K., Ji, X., Liu, J., Zhou, H., Tian, H., Li, X., & Liu, H. (2025). *Using piezoelectric technology to harvest energy from pavement: A review*. Journal of Traffic and Transportation Engineering (English Edition), 12(1), 68–86. DOI: 10.1016/j.jtte.2024.11.002. ScienceDirect+1
2. Gaber, H. M., & Abdel-Raheem, M. (2025). *Piezoelectric Energy Harvesting from Roadways: Challenges, Advances, and Future Directions*. Transportation Research Record, 2679(12), 760–779. DOI: 10.1177/03611981251353705. Sage Journals+1
3. Gholikhani, M., Roshani, H., Dessouky, S., & Papagiannakis, A. T. (2020). *A critical review of roadway energy harvesting technologies*. Applied Energy, 261, 114388. DOI: 10.1016/j.apenergy.2019.114388. ScienceDirect
4. Guo, L., & Lu, Q. (2017). *Potentials of piezoelectric and thermoelectric technologies for harvesting energy from pavements*. Renewable and Sustainable Energy Reviews, 72, 761–773. DOI: 10.1016/j.rser.2017.01.090. ScienceDirect
5. Qabur, A., & Alshammari, K. (2018). *A Systematic Review of Energy Harvesting from Roadways by using Piezoelectric Materials Technology*. Innovative Energy & Research, 7(1), 191. DOI: 10.4172/2576-1463.1000191. Online
6. *Research progress and latest achievements of road piezoelectric vibration energy capture technology based on intelligent transportation construction*. Intelligent Transportation Infrastructure. Oxford Academic.
7. *Cantilevered piezoelectric energy harvesting for road transportation energy systems: From vibration-structure coupling to circuit adaptation and field deployment*. Applied Energy, 426, 128521 (2026).