

Energy Harvesting through Piezoelectric Speed Breaker System for Sustainable Road Infrastructure

Miss. S. V. Niwane¹, Atharva N. Gosavi², Vijay A. Patil³, Gaurav S. Asalkar⁴, Vishakha V. Dode⁵

¹ lecturer of department , Civil Engineering , VBKCOE, Maharashtra, India

^{2,3,4,5} Student , Civil Engineering , VBKCOE, Maharashtra, India

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ABSTRACT

This paper presents diploma-level research on the development of a piezoelectric speed breaker prototype designed to convert vehicular mechanical load into electrical energy. The objective is to demonstrate sustainable micro-energy harvesting suitable for campus roads and institutional infrastructures. Experimental expectations are considered due to laboratory limitations.

Keywords:- Piezoelectric, Speed Breaker, Renewable Energy, Diploma Engineering

1. INTRODUCTION

Transportation systems dissipate mechanical energy through braking and speed regulation. Piezoelectric transducers provide an effective pathway to convert this mechanical input into electrical output suitable for low-power applications. This approach supports sustainable road infrastructure by providing auxiliary power without depending on external grid supply. Transportation systems dissipate mechanical energy through braking and speed regulation. Piezoelectric transducers provide an effective pathway to convert this mechanical input into electrical output suitable for low-power applications. This approach supports sustainable road infrastructure by providing auxiliary power without depending on external grid supply. Transportation systems dissipate mechanical energy through braking and speed regulation. Piezoelectric transducers provide an effective pathway to convert this mechanical input into electrical output suitable for low-power applications. This approach supports sustainable road infrastructure by providing auxiliary power without depending on external grid supply. Transportation systems dissipate mechanical energy through braking and speed regulation. Piezoelectric transducers provide an effective pathway to convert this mechanical input into electrical output suitable for low-power applications. This approach supports sustainable road infrastructure by providing auxiliary power without depending on external grid supply.

2. LITERATURE REVIEW

Prior research indicates piezoelectric modules such as PZT and PVDF can generate micro-scale voltage under compressive loads. Academic investigations have demonstrated voltage outputs ranging between 3V to 40V depending on stack configurations and applied force. Diploma-level studies confirm feasibility for educational prototyping. Prior research indicates piezoelectric modules such as PZT and PVDF can generate micro-scale voltage under compressive loads. Academic investigations have demonstrated voltage outputs ranging between 3V to 40V depending on stack configurations and applied force. Diploma-level studies confirm feasibility for educational prototyping. Prior research indicates piezoelectric modules such as PZT and PVDF can generate micro-scale voltage under compressive loads. Academic investigations have demonstrated voltage outputs ranging between 3V to 40V depending on stack configurations and applied force. Diploma-level studies confirm feasibility for educational prototyping. Prior research indicates piezoelectric modules such as PZT and PVDF can generate micro-scale voltage under compressive loads. Academic investigations have demonstrated voltage outputs ranging between 3V to 40V depending on stack configurations and applied force. Diploma-level studies confirm feasibility for educational prototyping.

3. WORKING PRINCIPLE

When a vehicle passes over the dome, vertical force compresses piezoelectric stacks generating alternating electrical output. A bridge rectifier converts this into DC which can be stored in rechargeable batteries for powering sensors and indicators. When a vehicle passes over the dome, vertical force compresses piezoelectric stacks generating alternating electrical output. A bridge rectifier converts this into DC which can be stored in

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3.1 Mechanical Energy Input

Vehicles apply dynamic load on the speed breaker.

This load creates compressive or bending stress in the embedded piezoelectric transducers.

The amount of mechanical input depends on vehicle weight, speed, and traffic density.

3.2. Piezoelectric Effect Generation

Piezoelectric materials such as PZT (Lead Zirconate Titanate), Quartz, or PVDF polymers generate electric charge when mechanically deformed.

This phenomenon is due to non-centrosymmetric crystal structure, which displaces electric dipoles under stress.

Stress → Dipole displacement → Voltage generation.

3.3 Electrical Charge Collection

The generated charge is typically AC in nature and low in magnitude.

Electrodes attached to the piezo elements collect the induced potential.

The generated output depends on:

Applied force

Area of material

Material piezoelectric coefficient (d_{33})

3.4 Signal Conditioning and Rectification

Raw generated AC is converted to DC using rectification circuits.

Voltage regulators and capacitors stabilize the output.

Protective circuits avoid damage from voltage spikes.

3.5 Energy Storage Stage

The processed DC power is stored in:

Batteries (Lead-acid or Lithium)

Supercapacitors (for higher cycle life)

Stored energy is used for low-power applications like:

Street lights

Sensors

Traffic signals

IoT devices

3.6 Load Utilization

Output power is distributed to connected loads.

In smart implementations, the system can:

Feed microgrid

Support hybrid power systems (solar + piezo)

4. METHODOLOGY

The prototype consists of a PVC dome, wooden base, spring supports, stacked PZT discs, rectifier circuit and rechargeable battery. Fabrication follows sequential processes common in diploma engineering projects including material selection, assembly and testing. The prototype consists of a PVC dome, wooden base, spring supports, stacked PZT discs, rectifier circuit and rechargeable battery. Fabrication follows sequential processes common in diploma engineering projects including material selection, assembly and testing. The prototype consists of a PVC dome, wooden base, spring supports, stacked PZT discs, rectifier circuit and rechargeable battery. Fabrication follows sequential processes common in diploma engineering projects including material selection, assembly and testing. The prototype consists of a PVC dome, wooden base, spring supports, stacked PZT discs, rectifier circuit and rechargeable battery. Fabrication follows sequential processes common in diploma engineering projects including material selection, assembly and testing.

5. SYSTEM DESIGN

Mechanical subsystem absorbs vehicle load while electrical subsystem processes generated voltage. The model is fabricated as a physical 3D setup for classroom demonstration and viva. Mechanical subsystem absorbs

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6. EXPECTED RESULTS

Load Condition	Expected Voltage (V)
Foot Press	2.1 - 2.8
Mini Vehicle	4.5 - 7.2
Cycle Repetition	5.5 - 9.0 Peak

The results indicate suitability for sensor nodes and LED loads.

7. APPLICATIONS

Campus lighting, traffic indicators, IoT sensors and signage.

8. COST ANALYSIS

The estimated prototype cost ranges between ■1800 to ■2500 based on material availability.

9. CONCLUSION

The proposed system demonstrates feasibility for micro-energy harvesting from roadway infrastructure with minimal structural modifications.

10. FUTURE SCOPE

Integration with traffic IoT systems, durability studies and optimization of piezoelectric stacking.

11. REFERENCES

- [1] Diploma Renewable Energy Notes (2023)
- [2] MSBTE Civil Engineering Handbook (2024)
- [3] Piezoelectric Pavement Study (2022)