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Sustainable Infrastructure: Power-Generating Piezoelectric Roads

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Abstract

Among all forms of energy, electricity is the most widely used. However, there is a significant shortage of electricity in today's world, which needs to be addressed. As we know, the number of vehicles on the road is increasing rapidly worldwide. The movement of these vehicles can be utilized to generate a considerable amount of electricity. Harnessing the waste energy produced by moving vehicles is both relevant and important, especially in high-traffic areas. When roads are engineered with piezoelectric technology, the pressure exerted by moving vehicles is captured by sensors embedded in the road. This pressure is then converted into electrical energy by piezoelectric transducers, which can be stored and used as a power source.

This paper focuses on the generation of alternative energy using piezoelectric materials. It explores how these materials can harvest energy from vibrations caused by moving vehicles for the purpose of energy generation and storage. The study also examines public perception and the adaptability of piezoelectric technology. Furthermore, the feasibility of implementing piezoelectric systems in real-world environments is analyzed by comparing the overall cost of electricity generation with that of solar energy.

Keywords: Energy harvesting, piezoelectricity, eco-friendly, green energy, piezoelectric generators, Vibrational Energy.

1. Introduction

In the face of rising global energy demands, the shortage of fuels and the environmental concerns, innovative technologies are being explored to create sustainable infrastructure. One such promising advancement is the integration of piezoelectric technology into road engineering. Roadways and pavements hold immense potential for harnessing clean energy ranging from mechanical and thermal to solar and wind as part of the global shift toward renewable resources. Mechanical energy generated from pavement due to repeated traffic loads and vibrations stands out as one of the most commonly occurring forms of renewable energy.

Piezoelectric materials have the unique ability to convert mechanical stress such as the pressure from vehicle tires into electrical energy. When embedded beneath road surfaces, these materials can harness the kinetic energy from passing vehicles and transform it into usable electricity.

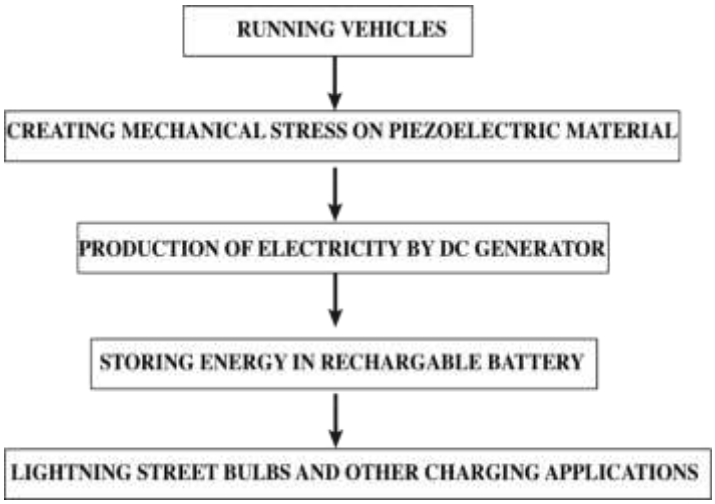
Beyond enabling energy-generating roadways, this technology supports broader initiatives in renewable energy adoption and smart city development. The harvested electricity can be utilized for powering street infrastructure, traffic management systems, or stored for grid supply. Moreover, piezoelectric sensors embedded in pavements can facilitate real-time traffic analytics and structural health monitoring.

Piezoelectric technology is based on the piezoelectric effect, a phenomenon where certain materials generate an electric charge when subjected to mechanical stress or pressure. This unique property has led to a wide range of applications in modern technology. Piezoelectric materials are used in sensors, actuators, medical ultrasound devices, lighters, and more.

2. OBJECTIVES

- To create electrical energy for running our appliances which are used in day-to-day activities.
- To utilize freely available renewable resources for generating energy rather than using exhaustible non- renewable resources.
- Such technology can be designed at every highway as an alternative source of energy to meet the increasing demand of energy.
- Piezoelectricity can be used for the lights on the either side of the road.

3. METHODOLOGY



- Piezoelectric transducers are wired in series to get collective output of good voltage and current.
- A layer of fine gravel and sand content is laid along with thin layer of asphalt which acts like a strong base for placing the generators.
- Wired Piezoelectric generators are placed in quick drying concrete as per design and left for some time.
- A bitumen sheet is used to cover all the generators to provide better adhesion of concrete to asphalt.
- Finally, a thick layer of asphalt is laid which finishes the construction.
- Sensors harvest the mechanical energy of the vehicles and convert to electrical energy.
- Electric energy is transferred and stored via harvesting module.
- Then it is charged into the battery on one side of the road. From there it is distributed.

Requirements form the cornerstone of any successful project, serving as the blueprint that delineates the purpose, features, and constraints of the system under development. At the inception of a project, understanding and articulating these requirements are fundamental steps that lay the groundwork for subsequent phases. The primary purpose of requirements is to establish a common understanding among stakeholders, providing a basis for effective communication, planning, and execution throughout the project life cycle.

Key Objectives of Requirements:

1. Clarity and Understanding
2. Alignment with Objectives
3. Guidance for Development
4. Verification and Validation
5. Change Management
6. Risk Mitigation
7. User-Centric Design

Table 1: Requirement of materials and instruments

Sl No	Materials Required	Instruments Required
1	Piezometer	Piezoelectric sensors
2	Asphalt or concrete	Power conditioning system
3	Subbase material	Data Acquisition system
4	Wiring and Electrical components	Battery or Energy source system
5	Control and Monitoring system	Installation equipment
6	Weather proofing materials	Maintenance and calibration tools
7	Support structures	Piezoelectric sensors

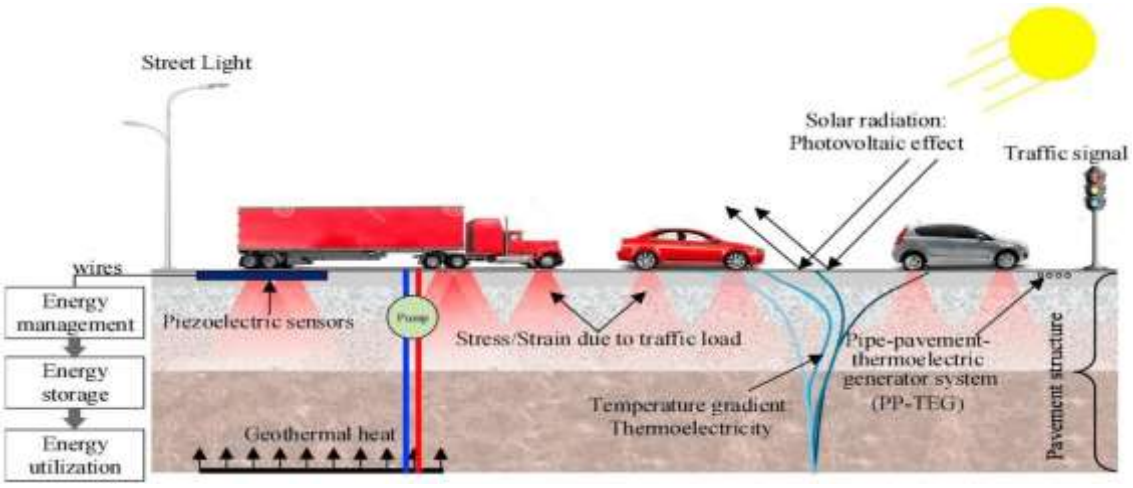
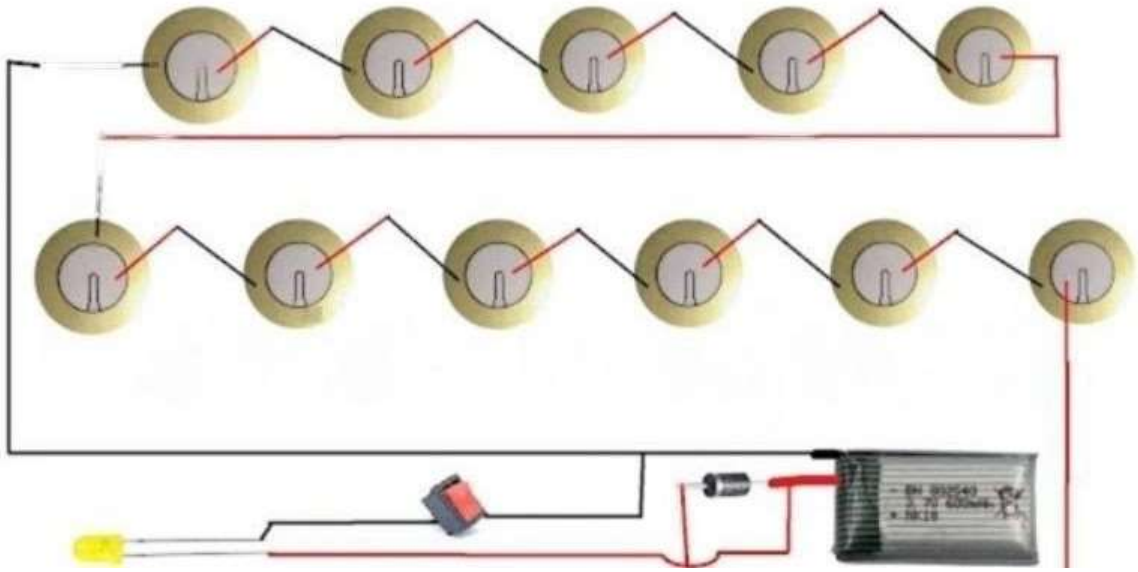


Figure 1: Systematic representation

3.1 SYSTEMATIC ANALYSIS



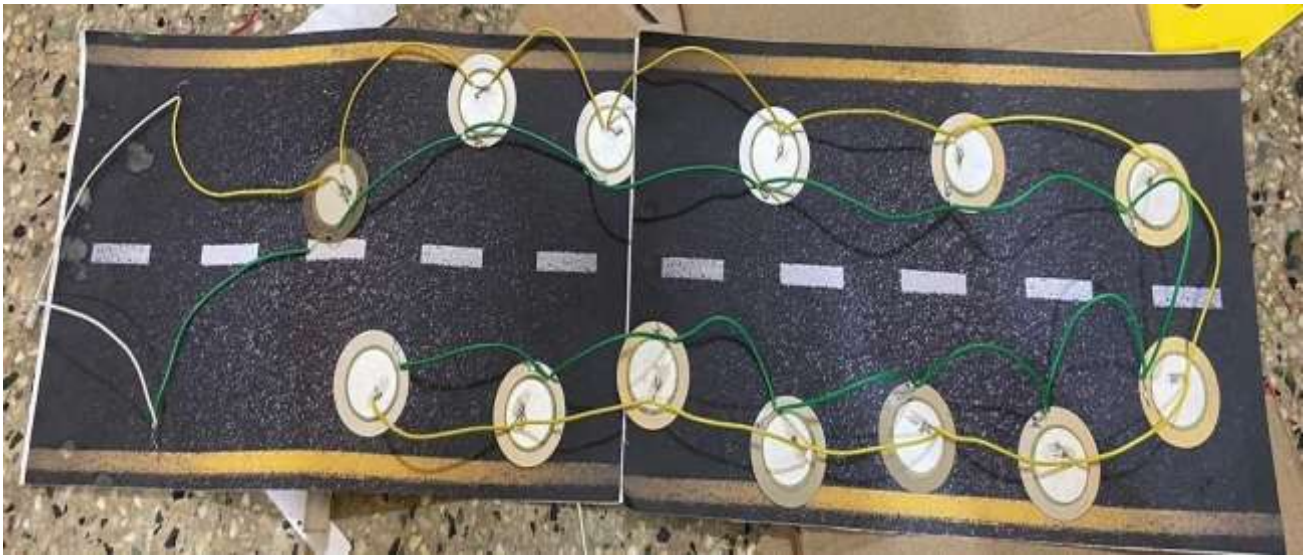


Figure 2: piezoelectric transducers series connection

3.2 COMMERCIAL VEHICLE SURVEY

- To calculate the number of vehicles moving on the road, vehicle survey is done for only commercial vehicles because commercial vehicles will have more self-weight and they carry heavy loads.
- Number and type of vehicles moving on the road is noted and those vehicles are converted into Public Car Unit (PCU).
- Those values are used to calculate the amount of electricity the sensors can generate.
- The vehicle survey was carried out at Ayyappa temple road in jahalli
- The calculations are shown in the table below

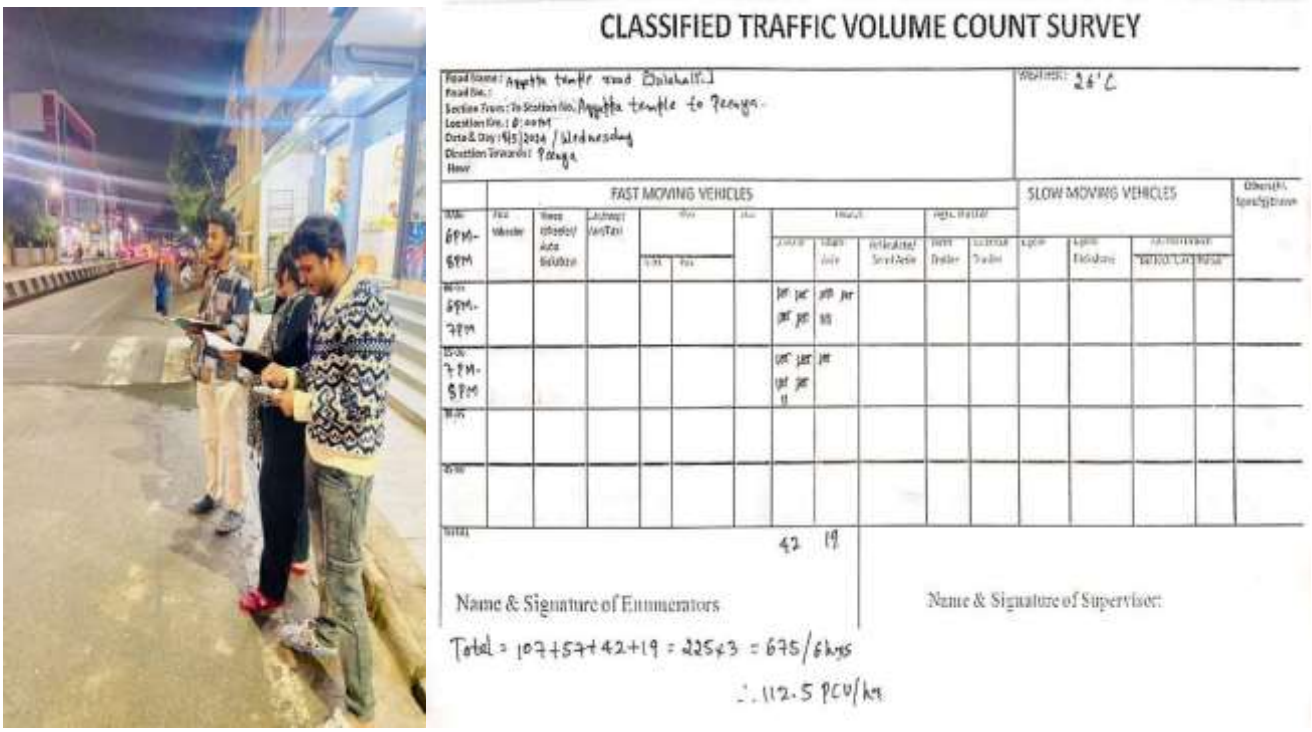


Figure 3: Traffic survey and traffic volume count survey

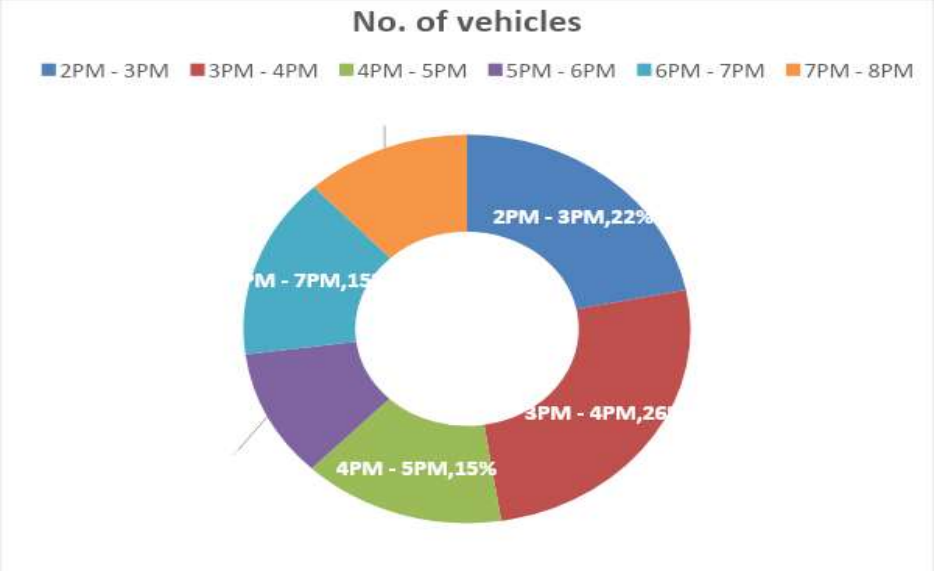


Figure 4: Chart for commercial vehicle reading

3.3 Experimental Data on Piezoelectric Plates

- Voltage / Piece: 2.8 V per pressure (avg)
- Current / Piece: 20 mA per pressure (avg)

3.4 Calculation for number of Piezo required for the model

- One Piezo generates 2.8V and 20mA. (Average)
- If 5 such Piezo's are connected in series then voltage developed is =2.8*5 =14V(20mA)
- To increase the current value, 5 series connected Piezo's has to be connected in parallel.
- Therefore 6 such parallel connections have to be done: I=6*20mA =120mA

3.5 Final test results and outputs

- Number of vehicle movement from 2 PM to 8 PM : 225
- Number of vehicles pressing the 210 mm x 297 mm mat: 225 X 3 = 675 numbers
- Considering the minimum voltage 1.13 V per pressure = 1.13 X 675 = 763Volts
- Total Power generate= V x I = 92 Watts
- As the voltage developed by Piezo varies with the pressure applied, minimum and maximum voltages obtained are as follows.
- To generate a voltage of 13.56V in time span Minimum voltage developed = 1.1V per pressure of wheel of light vehicle (Motor Bike).
- Maximum voltage developed = 2.8V per pressure of wheel of light vehicle (Motor Bike).

4. CONCLUSION

- This project introduces a low-cost piezoelectric disc energy harvesting technique to harness electrical power. Several tests were performed by allowing vehicles to pass over the model during peak hours. It was found that the voltage generated by two-wheelers was quite low, around 4–5 volts, whereas the maximum voltage generated by four-wheeler vehicles was about 10–12.5 volts.
- The energy harvested was stored in a battery connected to an inverter. In this way, the load on conventional energy sources can be reduced to a great extent. Furthermore, in the future, with more

discs connected, improved models could be proposed for traffic intersections, as the maximum vehicular load would result in greater energy harvesting.

- This can be used for many applications in rural areas where power availability is limited or completely absent, especially in a developing country like India, where energy management is a major challenge due to the large population. By using this system, both AC and DC loads can be powered depending on the force applied to the piezoelectric sensor.
- This will be a revolutionary step in energy production by integrating innovations and technologies to shape the future of energy. However, further focus is required to quantify the output and achieve greater power generation for it to become a reliable source of electricity.
- At a time when governments are finding it difficult to make land available for new power plants, extracting energy by utilizing the vast network of highways across the world seems like a highly lucrative proposition. However, this idea has not yet gained sufficient traction among policymakers, even though researchers have shown that energy can be extracted from highways by fitting them with piezoelectric devices, solar panels, wind turbines, and other energy-generating tools.
- Future of the world would depend on our ability to create a self-sustaining environment where everything could be put to some use and dependent on each other. The energy generating road designs could become a starting point for a self-sustaining future.
- We thus conclude that this thought will be a revolution in power production and curb down the energy costs thereby improving our country's economy. This energy is produced by consumers' participation without requiring any kind of input energy. Further concentration in the work would result in the better production of energy. We can see a better dimension of this piezoelectric concept in the futuristic world.

5. References

1. Yangsen Cao, Aimin Sha, Zhuangzhuang Liu "Electric energy output model of a piezoelectric transducer for pavement application under vehicle load excitation", Elsevier, Volume 211, 15 November 2020, 118595
2. Aoyagi, Y., Okada, M., & Fujii, H. (2012). Development of energy harvesting pavement and pilot test in Japan. Proceedings of the International Conference on Smart Materials and Nanotechnology in Engineering, pp. 93–98.
3. Dai, X., Zhang, Y., & Liu, J. (2014). Optimization of energy conversion circuits for piezoelectric energy harvesting. Energy Conversion and Management, 82, 91–98.
4. Goeij, P., Kock, S., & Hendriksen, G. (2015). Piezoelectric road for sustainable energy harvesting: A Dutch case study. Energy for Sustainable Development, 27, 105–111.
5. Liu, J., Xu, L., & Li, X. (2011). Harvesting energy from traffic: Piezoelectric systems in roadways. Energy Conversion and Management, 52(3), 1561–1567.
6. Sambandam, S., Mohan, S., & Ramasamy, R. (2015). Piezoelectric energy harvesting devices for road applications: A review. Journal of Energy Engineering, 141(3), 04014020.
7. Singh, R., Kumawat, N., & Gupta, S. (2018). Integration of piezoelectric energy harvesting systems with smart road networks. Renewable and Sustainable Energy Reviews, 82, 96–105.
8. Sodhi, R., Bhatia, R., & Gupta, M. (2019). Challenges in large-scale deployment of piezoelectric systems for roadways. Energy Reports, 5, 145–153.

9. Glynn, J., Nunes, D., & Davies, S. (2007). Piezoelectric materials for energy harvesting applications. Smart Materials and Structures, 16(3), 507–513.
10. Khan, M. S., Sood, V., & Kumar, S. (2017). Development of piezoelectric road poles for sustainable energy generation. Renewable Energy, 102, 315–324
11. Mitcheson, P. D., Yeatman, E. M., & Rao, G. (2008). Energy harvesting from vibration. IEEE Transactions on Industrial Electronics, 55(7), 2445–2453.