

Design of Piezoelectric Floor Tiles for Electricity Generation at Public Places Using Human Footsteps

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Abstract - This project focuses on designing and developing piezoelectric tiles that generate electrical energy from human footsteps. The system uses piezoelectric materials that create an electric charge when they experience mechanical stress from foot pressure while walking. By integrating piezoelectric sensors into floor tiles and connecting them with the right power conditioning circuits, we can convert the mechanical energy from everyday human movement into usable electrical energy. The generated power can be stored in batteries or capacitors and used for low-power tasks like lighting, sensors, and display systems in public areas. This method provides a sustainable, eco-friendly, and renewable energy solution, especially in busy places like railway stations, shopping malls, and sidewalks, helping to conserve energy and support green technology.

Keywords - Piezoelectric tiles, electricity generation, Piezoelectric materials, Energy Harvesting, Sustainable energy, LED sensors, Mechanical – to – electrical energy conversion.

I. INTRODUCTION

Piezoelectric tiles are innovative flooring systems that utilize the piezoelectric effect to generate electrical energy from mechanical pressure, such as footsteps. These tiles are embedded with piezoelectric materials like quartz, polyvinylidene fluoride (PVDF), or lead zirconate titanate (PZT), which produce an electric charge when subjected to stress. When people walk over these tiles, the pressure deforms the piezoelectric crystals, creating a small but usable amount of electricity. This energy can be stored or directly used to power low-energy devices such as LED lights, sensors, or digital signboards. Piezoelectric tiles are often installed in high-traffic public spaces like airports, train stations, shopping malls, and event venues, tapping into the otherwise wasted energy from daily pedestrian movement. Their use contributes to sustainable and green energy initiatives by providing

an alternative method of electricity generation without interfering with regular activities. With advancements in design and materials, modern piezoelectric tiles offer improved durability, efficiency, and even self-healing properties, making them a promising component in future smart infrastructures.

Advantages of Piezoelectric tiles:

1. They convert mechanical energy from footsteps into electrical energy without emitting pollutants.
2. Ideal for busy places like malls, railway stations, airports, and sidewalks, making use of otherwise wasted energy.
3. With proper design, they can handle significant load and last long with minimal maintenance.
4. Can be integrated with sensors for lighting, signaling, or energy monitoring systems.
5. Helps supplement electricity for low power applications, reducing load on the grid.
6. Promotes eco-friendly technology and awareness about renewable energy sources.

Objectives:

- To design and develop piezoelectric tiles capable of generating electricity from human footsteps.
- To study the efficiency of energy conversion from mechanical pressure to electrical energy.
- To explore cost-effective and practical materials suitable for constructing the tiles.

Problem Statement:

- High energy demand with rising urbanization and population.
- Wasted mechanical energy from human footsteps remains untapped.
- Need for a system to harvest footstep energy efficiently and reliably.

- Challenge to design durable piezoelectric tiles that can withstand human load and generate electricity.

Limitations of the Project:

- ❖ Limited Energy Output: Electricity generated per footstep is relatively small and may not meet large-scale energy demands.
- ❖ High Initial Cost: Manufacturing and installing piezoelectric tiles can be expensive compared to conventional flooring.
- ❖ Material Durability: Piezoelectric components may degrade over time under repeated heavy loads.
- ❖ Load Sensitivity: Tiles are designed for specific weight ranges; extreme loads may damage the system.
- ❖ Installation Constraints: Not suitable for all types of flooring or outdoor environments without protective measures.
- ❖ Maintenance Requirements: Requires periodic inspection and maintenance to ensure consistent energy generation.
- ❖ Environmental Factors: Performance may be affected by temperature, moisture, or dust in practical conditions.

II. LITERATURE REVIEW

1. D. Wadhwa et al, Elsevier (2019), “Designing and manufacturing a piezoelectric tile for harvesting energy from footsteps”. The research demonstrated that by employing a 10-gram tip mass, the resonance frequency of the piezoelectric module closely aligned with the vibration frequency of the tile at 22.5 Hz when subjected to an 80-gram steel ball dropped from a height of 1 meter. This alignment facilitated optimal energy transfer. Through impedance matching, the system achieved a matching value of 15 kΩ. Under these optimized mechanical and electrical conditions, the system was capable of harvesting 770 μW RMS and 55 mW peak output power. These findings underscore the importance of mechanical resonance and impedance matching in maximizing the efficiency of piezoelectric energy harvesting systems. For your project, these insights suggest that careful consideration of mechanical design parameters and electrical impedance is crucial for enhancing the performance of piezoelectric floor tiles.

2. Shreeshayana R, (2017), “Piezoelectric Energy Harvesting using PZT in Floor Tile (Prototype)”. The key findings from this paper show that individual PZT tiles can generate measurable outputs, typically in the range of a few milliwatts to a few hundred milliwatts per footstep, depending on the configuration. Studies highlight that proper sensor distribution, series or parallel connections, and well-designed rectification and filtering circuits significantly improve usable power. Mechanical improvements like frequency up-conversion mechanisms, cushioning layers, or spring-based load transfer systems enhance both efficiency and durability. While a single tile may only produce modest energy, scaling up to arrays of tiles in high-traffic zones can yield practical energy for small devices. Some prototypes achieved voltages above 30 V and successfully powered LEDs, demonstrating real-world applicability. These insights underline that careful optimization of design, durability considerations, and traffic-based scaling are essential for achieving reliable and efficient piezoelectric energy harvesting.

3. H. Anand et al, De Gruyter Brill, (2021), “Piezoelectric Energy Generation in India — empirical investigation”. The research highlighted several critical insights that can inform the design and implementation of piezoelectric energy harvesting systems:

- Energy Generation Potential: Piezoelectric materials can effectively convert the mechanical energy from human footsteps into electrical energy, providing a renewable energy source in densely populated areas.
- Cost-Effectiveness: When compared to solar energy systems, piezoelectric energy harvesting models can be more cost-effective and easier to implement, especially in urban environments where space and sunlight may be limited.
- Public Perception and Adaptability: The study found that public awareness and acceptance of piezoelectric technology are crucial for its successful adoption. Educational initiatives and demonstrations can enhance public understanding and support for such renewable energy solutions.

4. Disha Vashishth, (2022), “Viability of piezoelectric materials in India (railway station case study)”, IJ Publication (JETIR). Piezoelectric materials have

demonstrated the ability to effectively convert the mechanical energy generated by human footsteps into electrical energy, making them a promising renewable energy source for densely populated areas. Compared to solar energy systems, piezoelectric energy harvesting models can be more cost-effective and easier to implement, particularly in urban environments where space and sunlight availability are limited. Furthermore, the successful adoption of this technology depends on public awareness and acceptance. Educational initiatives and demonstrations play a key role in enhancing understanding and support for piezoelectric renewable energy solutions, facilitating their integration into everyday urban infrastructure.

5. Badgujar, (2025), “Efficient Energy Generation on Railway Platforms Using Piezoelectric Transducers”, Institutional / Conference via Research Gate. The study found that the electrical output from piezoelectric tiles depends strongly on the pressure applied and the time for which it acts, with higher force leading to greater energy conversion. The authors reported that a single step could generate up to 20 W under ideal conditions, though this figure is likely an upper estimate. Based on their calculations, they projected that one installation could generate about 0.11664 kWh per day and around 42.573 kWh annually. They also suggested that each system would cost approximately ₹12,511, with a projected lifespan of 15 years. While the research demonstrates the potential of piezoelectric tiles for energy harvesting, it also highlights challenges such as high system costs, variability in footstep pressure, and optimistic energy estimates compared to real-world conditions.

6.S. Sharma, (2022), A review of piezoelectric energy harvesting tiles”, TU Delft repository / Institutional. Sharma find that since about 2014 there has been a growing number of studies on piezoelectric tiles and flooring systems harvesting energy from human footsteps, with many prototype designs differing in mechanical layout, materials, and modes of embedding the piezo elements. They observe that although many designs exist, power outputs are often small (micro- to milli-watts) per tile under normal foot traffic, and much depends on how force is transmitted to the piezo material (tile thickness, backing, coupling) and what electrical circuits are used to extract, rectify, store, and

deliver usable voltage/power. The review discusses several circuit topologies (e.g. rectifiers, voltage multipliers, filters, storage elements) and shows that inefficiencies in these circuits often reduce the usable energy substantially. From the economic / feasibility side, the authors note that costs and durability are important barriers, as well as inconsistent footfall, variable loads, and mechanical wear. They also point out that many studies use optimistic assumptions when extrapolating to daily or annual energy figures. Finally, the review identifies key challenges (e.g. low power density, mechanical fatigue, optimizing material and design, cost reduction, integration into flooring that retains comfortable walking feel) and suggests future directions: improved design to enhance mechanical coupling, better circuit designs, testing under real usage, hybrid solutions, and standardization of evaluation metrics.

7.K. K. Selim, (2024), “Piezoelectric Sensors Pressed by Human Footsteps for Practical Energy Harvesting”. Selim report that with their tile of dimensions 455 mm × 405 mm instrumented with multiple piezoelectric elements, the maximum extracted power under stepping was about 249.6 milliwatts. They used a simple rectifier plus filter circuit to condition the harvested energy, and demonstrated that two LEDs could be lit by the energy produced. The authors also estimate that the cost of their prototype is about USD 10.2, which is relatively low for such a tile device. Their design uses mechanical features such as sandwiching plates and embedding glue sticks to pressure-transfer to the piezo sensors. Overall, the study provides a reasonable benchmark for what a floor tile might realistically offer in harvested power under stepping, and highlights tradeoffs between cost, mechanical design, and energy output.

8.IEEE Conf, Springer (J. Vibration Eng. & Tech.), (2024), “Energy Harvesting Floor Tile Using Piezoelectric Patches for Low-Power Applications”. The prototype tile (dimensions 455 mm × 405 mm) with piezoelectric patches mounted under a layered structure was able to successfully light two LEDs using the harvested energy. The authors measured a maximum useful harvested power of about 246 mW from a single footstep excitation. They estimated the cost of their prototype to be roughly USD 10.2 per tile, indicating a relatively low-cost implementation. Their

work also suggests that scaling up (i.e. using an array of such tiles) and testing under real pedestrian traffic environments (e.g. railway stations, subway halls) would be a logical future direction to increase energy yield.

9.Md. A. R. Laskar, “Piezoelectricity— An Energy Source for Future Railway Stations”, Institutional / Conference via Research Gate. There is already precedent for deploying piezoelectric floor tiles in high footfall areas (for instance, ticket gates, platform walkways), and that roadways and rail tracks themselves offer promising sites for embedding piezo patches or stack-type piezo harvesters. The paper proposes three main —aspects| or sources around a railway station to deploy piezoelectric materials: footpaths/platforms, nearby roads with vehicular traffic, and under the rails themselves. It includes schematic designs, for example piezoelectric patches or stacks under rail tracks that sense rail vibration or displacement and generate power. The work argues that while piezoelectric generation alone is unlikely to completely power a station, partial contributions are feasible; combining sources, optimizing placement, and integrating power management and storage (batteries etc.) could make a significant difference. The paper identifies key challenges: modest power density, mechanical durability, requirement of proper force transmission, and the need for cost-benefit analysis under real usage. Also, it highlights the importance of integrating storage / power management and perhaps combining with other renewables to achieve meaningful energy contribution.

10.Shubham Singh, “Energy Harvesting Using Piezoelectric Floor Tiles”, International Journal for Innovative Research in Science and Technology. The study demonstrates that piezoelectric floor tiles can effectively convert mechanical energy from human footsteps and ambient vibrations into usable electrical energy. The research highlights that these tiles are suitable for deployment in high-footfall areas, such as commercial spaces, pavements, and roads, to harness renewable energy. Integration with energy storage systems, such as supercapacitors or batteries, is emphasized as essential for ensuring a continuous and reliable power supply from the harvested energy. Additionally, the paper discusses advancements in material selection and device design that improve both

the efficiency and durability of the tiles, making them practical for real world applications. Overall, the findings support the feasibility of using piezoelectric tiles as a sustainable energy solution in urban environment.

III.METHODOLOGY

1. Project title selection:- The first step is to select a suitable title for the project. The title we chose is —Design and application of piezoelectric floor tiles for electricity generation at public places using human footsteps| which clearly shows that the project is based on converting human footsteps into electrical energy with the help of piezoelectric materials.
2. Problem identification and objective:- In this step, the main problem of increasing energy demand and wastage of kinetic energy from human footsteps is identified. The main objective of this project is to design and develop piezoelectric tiles capable of generating electricity from human footsteps.
3. Estimation of energy generation potential:- In this step, an estimation of how much energy is generated from a single footstep needs to be done. This involves the calculating of voltage and current output expected from the piezoelectric tiles based on pressure applied and the number of tiles.
4. Selection of piezoelectric tile material:- Various piezoelectric materials such as PZT, PVDF, and quartz are discussed and compared. According to availability, price, and effectiveness, the best material is chosen that can provide superior energy output and is convenient to use for tile making.
5. Designing of tiles:- In this step, the tile's design and size is decided. The size of the tile that we have decided is 30cm X 30cm. The design is done in a manner so that it can bear the weight of footsteps well and transfer pressure to the piezoelectric elements efficiently. The uppermost surface must be strong and anti-slipping for walking safety.
6. Circuit Design and Storage System:- The produced electrical power from the tiles is in a non-regular shape, so the right circuit is planned. It consists of rectifiers to transform AC to DC, capacitors to smooth voltage, and a storage component such as a rechargeable battery or capacitor bank to accumulate the produced power.

7. Prototype development:- After the design and circuit preparation, a small prototype model of the tile system is developed. This prototype is made to check how the system will work in real conditions and to find any possible improvements before making a large-scale setup.
8. Laboratory testing:- Laboratory testing will be done in the project stage – II. The developed prototype will be tested in the lab under controlled conditions. Different loads and frequencies of footsteps will be applied to measure the voltage and current output. The data will also be collected for analysis to understand the actual performance of the system.
9. Performance analysis and optimization:- During this phase, results from the test will be used to verify the effectiveness of the system. If the energy output is unstable or low, certain alterations are made such as addition of alternative process to enhance the energy output, tile material, or connection type in order to enhance performance.
10. Final documentation and recommendation: - Once all the experiments and analysis are completed, the entire work will be documented appropriately. Final results, graphs, and conclusions are included, along with potential future enhancements or suggestions for large-scale application.

IV. CONCLUSION

In this project, a concrete base was used to absorb vibrations, a transparent acrylic sheet provided support and visibility, and nine piezoelectric sensors arranged in a grid were connected in series-parallel to improve voltage and current output. A rubber sheet on the top ensured slip protection and effective transfer of foot pressure to the sensors. The results prove that piezoelectric tiles are a clean, renewable, and eco-friendly energy source, suitable for places with heavy human movement such as railway stations, malls, footpaths, and campuses. Although the power generated is small, it can be effectively used for low-power applications like LEDs and sensors. With further improvements, this technology has good potential for sustainable energy generation in the future.

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