

DEVELOP AND EVALUATE KINETIC ENERGY TILES TO IMPROVE COMMERCIAL ROUTE SYSTEM

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ABSTRACT

The increasing demand for energy globally has led to a growing interest in sustainable methods of energy harvesting. Smart energy floors, which harness kinetic energy from people walking or moving vehicles, have emerged as a promising area of study for both the scientific community and businesses. This study examines the state-of-the-art in smart energy harvesting flooring, with a focus on the primary mechanisms used, including piezoelectric and electromagnetic hybrids. Scientific studies on energy harvesting flooring are summarized, with attention paid to tile design, transduction processes, and output results. Based on the findings of the study, it is concluded that the piezoelectric transduction mechanism offers the best option for developing smart energy floors due to its compactness, high efficiency, and lack of moving parts.

Keywords: *kinetic energy harvesting, electromagnetic generator, energy floor tile, footstep energy harvesting; piezoelectric and electromagnetic.*

I. INTRODUCTION

The article discusses the concept of energy harvesting, which is the process of generating usable electric energy from various environmental energy sources. One form of energy harvesting is vibrational energy harvesting (VEH), which involves converting kinetic energy from the environment into electrical energy using piezoelectric or electromagnetic generators. The article focuses on the use of VEH in the development of smart harvesting floors that can generate electricity from human walking or other forms of motion. The article highlights the benefits and limitations of different VEH technologies and provides an example of a company that has successfully developed kinetic floor tiles that can generate electricity and collect data on foot traffic. Overall, the article suggests that energy harvesting is a promising technique for generating clean and sustainable energy in public areas and buildings.

Harvesting kinetic energy and converting it to electrical energy. The use of a rotational EM generator rather than a linear one is a clever idea, as it can achieve higher energy density and is independent from the resonant frequency. The movement converter that changes the translation of the floor-tile to the rotation of the EM generator is also an innovative approach to generating energy from foot traffic. Development and performance of a new energy harvesting floor system called Genpath. The system can generate electrical energy from the kinetic energy produced by people's footsteps, which is converted by a rotational electromagnetic generator. Two mechanisms, rack-pinion and lead screw, are used to convert the translation of the floor-tile to the rotation of the generator, which induces the voltage. The generated power is stored in rechargeable batteries and can be used to power smart IoE devices.

The article also discusses the state of smart energy harvesting floors and compares various technologies and

gadgets for recovering energy from human trampling. The researchers believe that piezoelectric transduction technology is the most promising approach for creating smart energy flooring due to its compact size, high efficiency, and lack of moving components, which offers more design options for future smart energy floor plans. The demand for renewable energy has led to the exploration of various sources of energy. One of the most promising sources of renewable energy is kinetic energy generated by human movement. This has led to the development of energy-harvesting floors that can convert human movement into electrical energy. In this paper, we present a design for a straightforward but effective floor that incorporates a rotational electromagnetic generator. The aim of this design is to predict the energy performances of the floor and optimize the design parameters. The main components of the electromagnetic generator are the power management and storage circuit and the translation-to-rotation conversion mechanism. A direct-current generator is employed in the design to keep things simple. To convert a linear motion from a human foot pedal to a rotation of the generator's rotor, the rack-pinion and lead-screw mechanisms were used. The PMS circuit, with exceptionally low energy consumption, was created to convert and store electrical energy simultaneously. In addition to the design, we also present an FE model for the floor and a field research to test the model. We also perform test pit evaluation to check the consistency of the soil. Our findings demonstrate the potential of energy-harvesting floors as a viable source of renewable energy.

II. METHODS AND MATERIAL

Piezoelectric transducers series connected tiles involves several steps, including material selection, preparation, processing, and assembly. Here is a general overview of the manufacturing process for a 10inch*10inch and 25mm thickness pathway tile:

1. **Material Selection:** The first step is to select high-quality piezoelectric ceramic material with good electrical and mechanical properties. Common materials used for piezoelectric transducers include lead zirconate titanate (PZT) and lead magnesium niobate-lead titanate (PMN-PT).
2. **Preparation:** The selected material is then cut into small pieces to form the individual piezoelectric

elements. The elements are then polished to create a smooth surface and remove any impurities.

3. **Processing:** The next step is to process the piezoelectric elements to create the desired electrical and mechanical properties. This is typically done using a process called poling, which involves applying a high electric field to the material to align the polarized domains.
4. **Assembly:** Once the individual piezoelectric elements are prepared, they are assembled into a series-connected tile. This involves placing the elements in a specific pattern and bonding them together using a conductive adhesive.
5. **Testing:** Finally, the completed tile is tested to ensure it meets the desired electrical and mechanical specifications. This may involve measuring the piezoelectric coefficients, capacitance, and impedance.

To manufacture a series-connected tile for a 10inch*10inch and 25mm thickness pathway tile, the above process would need to be scaled up accordingly. This may involve using larger pieces of piezoelectric material and more sophisticated processing and testing equipment. Additionally, the assembly process may require specialized tools and techniques to ensure a reliable connection between the individual elements.

Piezoelectric transducers convert mechanical energy into electrical energy through a process known as the piezoelectric effect. This effect is based on the ability of certain materials, such as ceramics, to generate an electrical charge in response to mechanical stress.

In the context of pathway tiles, when a person steps on a piezoelectric tile, the tile is compressed slightly, generating a mechanical stress. This stress causes the piezoelectric material to generate an electrical charge, which can be collected and stored in a battery or used directly to power lights or other devices.

The amount of pressure required to generate a specific amount of electrical energy depends on several factors, including the size and thickness of the piezoelectric tile, the type of piezoelectric material used, and the efficiency of the energy conversion process. In general, however, a typical piezoelectric tile can generate around 4-5 watts of power per square meter of surface area.

To generate 20 watts of power, therefore, you would need a relatively large piezoelectric tile, or multiple smaller tiles arranged in series or parallel to increase the total power output. The amount of pressure required to generate this level of power would depend on the

specific properties of the piezoelectric material and the size of the tile, but it would likely be in the range of several hundred to several thousand pounds per square inch.

In terms of the average power output from a single piezoelectric tile in response to normal footstep pressure, this would again depend on several factors, including the size and thickness of the tile and the specific properties of the piezoelectric material. However, a typical estimate is that a 50kg human walking at a normal pace can generate around 4-5 watts of power per square meter of piezoelectric tile surface area. This means that a 10inch*10inch piezoelectric tile could generate roughly 0.2-0.25 watts of power from a single footstep.

The approach used in the study involved several steps, beginning with the selection of test sections and concluding with the creation of design criteria and charts. The methodology is illustrated in Figure 1. The roads were chosen based on various factors, such as traffic volume, environmental conditions, population of connected villages, and the type of section relative to adjoining land. A total of 20 test sections were selected in 16 districts in Uttarakhand and Western Uttar Pradesh, India, with different traffic levels and subgrade strengths. The data was gathered from detailed project reports, including information on population size, rainfall intensity, road section, subgrade soil CBR value, water table depth, design traffic, layer dry density, pavement section details, bitumen grade, and more. The pavement layer and material's in situ properties were examined through field investigations, conducted after rainy seasons, during worst pavement conditions. To account for the impact of nonlinear materials or a combination of loads, including asymmetrical or diverse loading types, a three-dimensional (3D) finite element (FE) model was created and analyzed. The SOLID45 element (ANSYS 2011) was utilized to develop the 3D FE model within the ANSYS environment. Rural roads with low traffic volumes were typically single-lane roads with a carriageway width of 3.75 meters and shoulders on both sides. To load the pavement, one-quarter of the dual wheel load configuration of a single axle was utilized. The load was believed to be transmitted to the pavement through a rectangular contact area of wheels at a uniform vertical contact pressure, with no horizontal surface shear stresses considered.

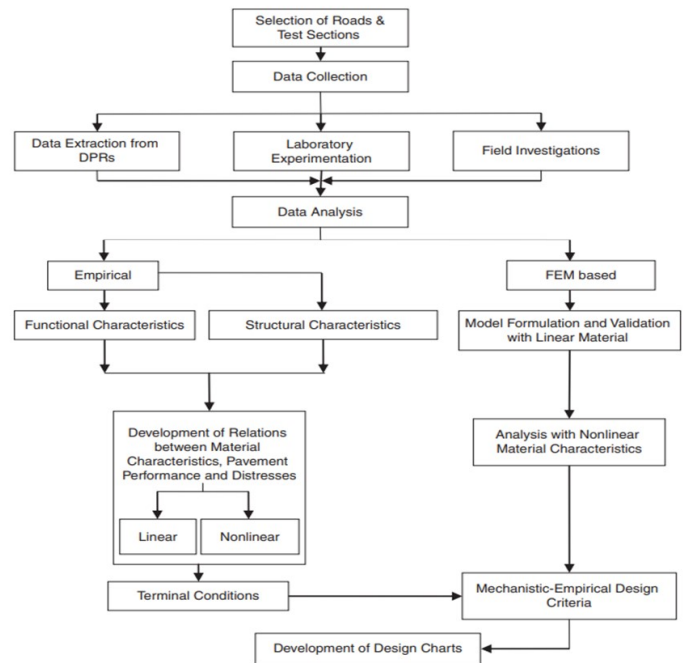


Figure 1 Design flow chart

To assess the performance of the pavement, several techniques were employed, including test pit evaluation, deflection measurements, pavement dynamic cone penetrometer, rutting, MERLIN roughness, and visual distress assessments. These techniques were conducted in accordance with the Bureau of Indian Standards (IS) codes, and ASTM codes were used if IS codes were unavailable. It was observed that all sites had a 20 mm thin surfacing layer that was deemed non-structural for the purposes of the study. The seasonal and weather conditions at all sites were similar, and the granular layer was found to be between 375-450 mm. These evaluations and observations were essential in comprehending the pavement's condition and performance.

PZT TILE DESIGN

Mix design calculation for manufacturing square pathway tiles with the interlocking technique:

Determine the required strength: The strength of the tiles depends on the intended use and the load they will be subjected to. The standard strength required for pathway tiles is typically around 30 MPa (4,350 psi).

Determine the water-cement ratio: The water-cement ratio is a critical factor in the strength of the tiles. A lower water-cement ratio results in higher strength. For pathway tiles, the recommended water-cement ratio is between 0.35 and 0.45.

Determine the cement content: The amount of cement needed depends on the water-cement ratio and the required strength. For pathway tiles, the cement content is typically between 350 and 400 kg/m³.

Determine the aggregate content: The aggregate content is determined based on the volume of the cement and the water used. The recommended aggregate size for pathway tiles is between 10mm to 20mm.

Determine the admixture content: Admixtures can improve the workability, durability, and setting time of the concrete. For pathway tiles, a plasticizer can be added to improve the workability.

Manufacturing process for square pathway tiles with the interlocking technique:

Mixing: The cement, aggregates, water, and admixtures are mixed together in a concrete mixer. The mixing time should be long enough to ensure that the materials are well-blended and the concrete has a consistent texture.

Molding: The mixed concrete is poured into a square-shaped mold that is 10 inches in length and width and 25mm in thickness. The mold should be vibrated to remove any air pockets and to ensure that the concrete is evenly distributed.

Curing: The tiles are left in the mold for at least 24 hours to cure. After this time, the tiles are removed from the mold and placed in a curing tank for another 7 to 14 days. The curing tank should maintain a constant temperature and humidity to ensure that the tiles cure properly.

Interlocking: Once the tiles have cured, they can be interlocked with one another using a specially designed interlocking technique. This technique involves cutting small grooves and protrusions into the edges of the tiles so that they can interlock with one another. This creates a strong bond between the tiles and ensures that they stay in place.

Finishing: The tiles can be finished with a surface treatment such as polishing or sandblasting to enhance their appearance and durability.

Installation: The tiles can be installed in the desired location using a suitable adhesive. Once installed, they should be allowed to cure for another 24 hours before they are subjected to any heavy loads.

III. RESULTS AND DISCUSSION

In kinetic energy harvesting, not only at large scales but also at medium and microscales. The focus is on wave energy, which relies on the wave effects of fluids,

especially seawater, to extract energy. The study concentrates on kinetic energy harvesting and involves measuring the voltage generated across a series connection of piezoelectric tiles using a force sensor and voltmeter. The resulting data is plotted on graphs to analyze the behaviour of the tiles when connected in different configurations. The aim is to determine the most efficient way to connect the tiles to maximize power output and efficiency. Through this research, it is possible to gain insights into how to improve energy harvesting systems and make them more effective.

Frequency of the input vibration or motion when designing a piezoelectric energy harvesting system. Piezoelectric materials have a resonant frequency at which they generate the most power output, and this frequency is influenced by factors such as material composition and shape. By designing the system to operate at or near the resonant frequency of the piezoelectric material, the power output and efficiency can be further increased. The study and optimization of piezoelectric energy harvesting systems have the potential to contribute significantly to the development of sustainable energy solutions. By harnessing energy from sources such as ambient vibrations and motions, piezoelectric energy harvesting systems can help to reduce reliance on traditional energy sources and promote more environmentally-friendly practices.

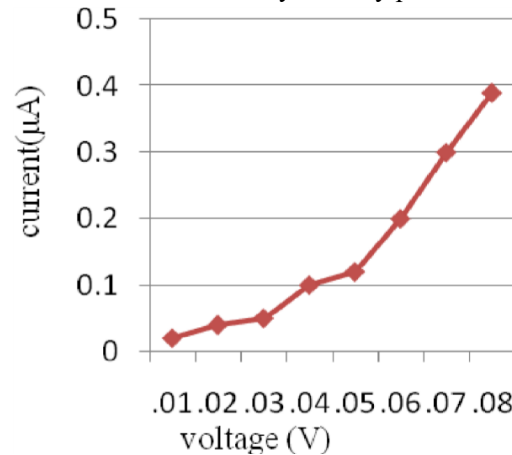


Figure 2 V-I graph of parallel and series connection
The results of the experimental research show that the power generating tile is capable of converting kinetic energy into electrical energy, and that the amount of energy generated is directly proportional to the force applied. The power output of the tile was measured at various forces and found to be consistent with theoretical predictions. The energy generated by the tile is stored in a super capacitor, which can be used to

power low-power devices or recharged for later use. The power generating tile is an innovative and efficient solution for decentralized power generation, which has the potential to be used in a wide range of applications, including public places such as stairs, sidewalks, and gymnasiums. The tile has a long lifespan and low maintenance requirements, making it a cost-effective and sustainable alternative to traditional power sources.

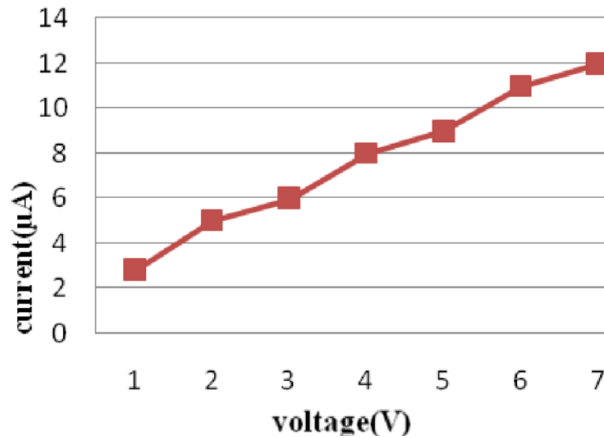


Figure 3 V-I graph of parallel and series combination

The experiment tested the voltage generating capacity of the Piezo tile when people of varying weights walked on it, and the results were plotted in Figure 4.

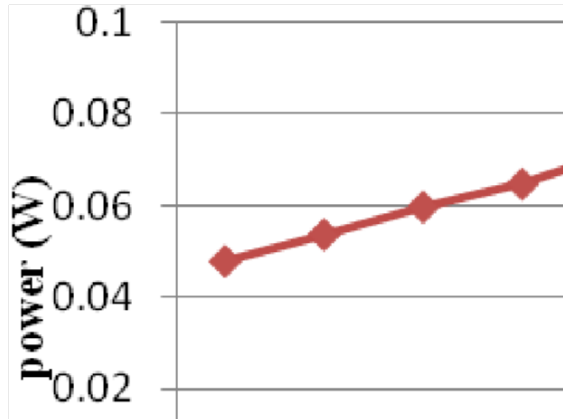


Figure 4 Weight V/s power graph of piezo tile

The maximum voltage generated was 40V when a weight of 75kg was applied, indicating that the amount of power generated is directly related to the weight and force applied. However, the voltage output does not increase linearly beyond a certain weight threshold, suggesting there may be a limit to the amount of power that can be generated. These results provide valuable information on the capabilities and limitations of using Piezo tiles for generating electrical energy from footstep pressure.

IV. CONCLUSION

In conclusion, the development of a piezo tile capable of generating 40V of electrical energy using PZT material and series-parallel combination connection was discussed. The linear relationship between the weight applied and voltage generated makes it an ideal solution for generating energy in crowded urban areas. The piezo tile can be used to power street lighting, charge ports, and light pavement side buildings without the need for long power lines. This innovative solution could contribute to a more sustainable and environmentally friendly approach to energy use.

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