



ECO POWER: PIEZO TILE FOR SUSTAINABLE ENERGY HARVESTING

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Abstract: This project generates electrical energy from human footsteps using piezoelectric sensors placed under a footstep tile. When a person steps on the tile, pressure is applied to the sensors, which convert mechanical energy into electrical energy. The generated power passes through rectifiers and voltage regulators and is stored in batteries or capacitors. An ATmega328 microcontroller monitors the system and displays data on an LCD. This eco-friendly system can be used in crowded public places to produce small amounts of renewable energy.

Keywords: Energy harvesting, Piezo tiles, Piezoelectricity, Renewable energy.

I. INTRODUCTION

This project focuses on generating electrical energy from human footsteps using piezoelectric technology. Every day, a large amount of mechanical energy is wasted when people walk in public places. This project converts that wasted energy into useful electrical power in a simple and eco-friendly way. Piezoelectric sensors are placed under specially designed footstep tiles. When a person steps on the tile, pressure is applied to the sensors, producing small amounts of electricity through the piezoelectric effect. The generated power is processed using electronic components such as diodes, capacitors, and resistors to make it stable and usable. An ATmega328 microcontroller controls the system, while an LCD display and LEDs show the generated power. Although a single step produces only a small amount of energy, continuous footsteps in crowded areas can generate useful power for low-power applications such as LED lighting, display boards, and charging small devices. In this fig-1 shown about the acrylic sheet with piezo.

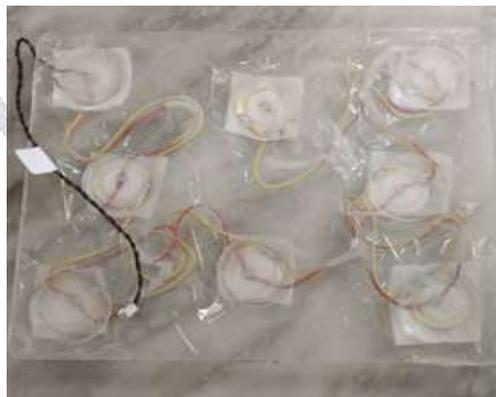


Fig-1: Acrylic sheet with piezo

Piezo tiles can be installed in public places like railway stations, shopping malls, bus stops, schools, and airports where many people walk daily. This system is eco-friendly, pollution-free, and does not require fuel. It also helps students and researchers understand renewable energy, the piezoelectric effect, microcontrollers, and energy conversion, while promoting sustainable and smart energy solutions for the future.

II. Literature

M. Ben Zohra et.al. [1]: This study focuses on generating electrical energy from road vibrations using a combination of Shape Memory Alloys (SMAs) and piezoelectric materials. SMAs help control excessive vibrations and reduce mechanical stress, which increases system durability. At the same time, piezoelectric tiles convert pressure from moving vehicles into electrical energy. Simulation results showed that the system produced 36% more power and had a 67% longer operational life than traditional methods. The study also highlights proper material placement and control strategies. Future research aims to reduce cost and test the system in real road environments. M. Ikbal et al. [2]: This research developed an energy harvesting system using flexible PVDF piezoelectric sheets placed inside a rotating vehicle tire. As the tire rotates, bending and deformation generate electrical energy

through the piezoelectric effect. A TPU end-cap protects the piezoelectric material from heat, pressure, and mechanical stress. The system produced a maximum output of 63 V and 3.42 mW of power. It charged a 22 μF capacitor to 14 V in less than 75 seconds. Experiments at different speeds and loads showed stable performance, making the system suitable for powering wireless tire sensors.

L. Mendes dos Santos et al. [3]: This study examines the use of PZT piezoelectric tablets to harvest energy from vibrations in agricultural machinery. Researchers tested different electrical connections such as series, parallel, and hybrid configurations. Two rectification methods were also analyzed to convert AC power into usable DC power. The hybrid configuration with diode bridge rectification produced the highest power at resonance frequency. When vibration moved away from resonance, the parallel connection performed better. The series connection showed the lowest output. The results provide useful guidelines for designing reliable energy harvesting systems for powering sensors in agricultural environments.

F. Mizrak et al. [4]: This study presents a hybrid decision-making model to select the best piezoelectric materials for energy harvesting in smart city applications. Several materials such as BaTiO₃, ZnO, PZT, PVDF, and quartz were evaluated based on efficiency, cost, durability, scalability, and environmental safety. BaTiO₃ ranked highest because of its durability and environmental friendliness. ZnO ranked second due to its low cost and easy scalability. Although PZT showed high energy efficiency, it contains lead, which raises environmental concerns. The model helps engineers choose suitable materials for sustainable energy harvesting systems.

W. Guo et al. [5]: This research introduces a compact broadband piezoelectric energy harvester designed to collect vibration energy over a wide frequency range. The system has two resonance frequencies at 48 Hz and 62 Hz, allowing energy harvesting between 35 and 90 Hz. A dual-capacitor SDCS-SECE circuit improves power extraction and prevents energy backflow. Experiments showed that the proposed system produced up to 390% more power compared to standard interfaces. Environmental tests confirmed stable voltage output. The harvested energy successfully powered a wireless accelerometer, showing its potential for self-powered IoT sensors in varying vibration environments.

W. Kang et al. [6]: This review paper compares traditional piezoelectric energy harvesting methods with new approaches based on ferroelectric and ferroelastic switching. Conventional systems produce low power and work efficiently only within a narrow frequency range. Switching-based techniques improve energy density by controlling polarization and mechanical stress. The paper also discusses advanced structural designs such as zigzag beams, spiral structures, metamaterials, and porous architectures that increase strain and expand the operating frequency range. Advanced piezoelectric ceramics and flexible polymers are also highlighted as promising materials for efficient, durable, and miniaturized energy harvesting devices.

A. Alsaad et al. [7]: This study developed a hybrid energy harvester integrated into footwear. The system combines piezoelectric and electromagnetic energy harvesting techniques. A metal cantilever with neodymium magnets moves over electromagnetic coils, while a piezoelectric layer captures energy from bending and foot impact. The device produced a maximum power of 577 μW during testing. The piezoelectric part generated an open-circuit voltage of 1.605 V, while electromagnetic coils added 15–16 μW of extra power. The system was created using 3D printing, making it compact and lightweight. It can power small wearable electronics during walking or running.

W. Xiu et al. [8]: This research presents a hybrid piezoelectric–electromagnetic energy harvester with a tunable resonance system. The resonance frequency can be adjusted by changing the distance between magnets from 48 mm to 68 mm. Nonlinear magnetic forces help widen the operating frequency range. A bending-mode piezoelectric transducer improves energy conversion efficiency. Experimental results showed a peak output of 9.1 mW at 18 Hz and 2 g acceleration. Double resonance peaks were observed at certain magnet distances, increasing performance. The compact and adjustable design allows the system to work efficiently under different vibration conditions.

M. Asis et al. [9]: This study used Smoothed Particle Hydrodynamics simulations to analyze a system combining flexible piezoelectric nanogenerators with perforated baffles. The design reduces liquid sloshing in tanks while generating electrical energy. A 3×3 baffle grid reduced sloshing motion energy by 76.42% and sloshing height energy by 45.20%. A denser 4×4 grid increased energy harvesting up to 145.2 mW per cubic meter but reduced sloshing control. Experimental tests confirmed the simulation results. The study highlights the balance between structural stability and energy generation for marine and offshore applications.

O. Hussein et al. [10]: This study presents a hybrid energy generation system combining solar-tracking photovoltaic panels with piezoelectric footstep energy harvesting. The solar panels produced up to 1.87 kWh of energy per day during summer. The piezoelectric system, with 48 sensors installed in 12 steps, generated 0.12 to 0.42 kWh per day from pedestrian movement. A smart controller maintained a stable 12 V DC output and managed battery charging. Testing with 150 users confirmed reliable performance. The hybrid design improved energy availability and reliability compared to using solar or piezoelectric systems separately.

A. Megdich et al. [11]: This study developed flexible piezoelectric devices using 3D printing by combining PVDF with barium titanate nanoparticles in bio-inspired structures. Different BT concentrations were tested, and 30% BT showed the best performance by increasing the piezoelectric β -phase content and electrical output. The device generated 30.8 V and charged a 1 μF capacitor to 25 V in 260 seconds. Durability tests confirmed stable operation after 1,400 loading cycles. However, excess BT caused particle clumping and reduced flexibility. Finite element analysis optimized the structure, showing the potential of additive manufacturing for flexible, self-powered electronic systems.

T. Yang et al. [12]: This research developed a high-output piezoelectric nanogenerator using CsPbI₃ nanorods embedded inside electrospun PVDF fibers. The aligned structure enabled self-polarization, eliminating the need for an external electrical poling process. The device produced an output voltage of 81.18 V and a current density of 0.78 $\mu\text{A}/\text{cm}^2$, which was enough to power LEDs and charge capacitors. The nanogenerator also showed excellent durability, maintaining stable performance under high temperatures, water exposure, and more than 10,000 mechanical cycles. This method offers a scalable and reliable way to produce flexible energy harvesters for small electronic devices.

B. Oladapo et al. [13]: This review discusses stretchable, biodegradable, and self-healing piezoelectric materials for implantable medical devices. These materials harvest energy from mechanical and thermal movements in the human body to power medical implants. Nanofillers such as BaTiO₃ and ZnO improve electrical output and sensitivity. Flexible structures like coiled, porous, and wavy designs help devices move naturally with body tissues. Self-healing elastomers repair mechanical damage and increase device lifespan. The study highlights the need for lead-free and biocompatible materials. It also recommends better encapsulation, improved filler dispersion, and more in-vivo testing for safe medical energy harvesters.

M. Derraz et al. [14]: This study developed a predictive model to estimate energy output from BaTiO₃/PLA piezoelectric composites under mechanical strain. The composites contained 20–60% ceramic content and were tested at 6 Hz frequency. Results showed that higher strain and higher ceramic content increased current output. The best performance occurred at 1% strain with 60% BaTiO₃, producing 413.06 nA current and about 4.5 μW power. However, performance improvement reduced beyond 40% ceramic due to increased stiffness. The predictive model matched experimental results and helped identify optimal compositions for eco-friendly energy harvesting devices.

J. Leppe-Nerey et al. [15]: This research investigated PVDF/PMMA composite films

enhanced with multi-walled carbon nanotubes for harvesting energy from tire deformation during vehicle motion. Different CNT concentrations were tested, and 0.05% MWCNT provided the best dispersion and highest electrical output. Under this condition, the system generated up to 4.3 kWh of energy over 100 km of driving. Higher CNT content reduced performance because of material saturation and reduced flexibility. A special experimental setup simulated real tire stress. Compared to pure PVDF films, the composite showed better energy harvesting performance. D. Yang et al. [16]: This review explains recent advancements in piezoelectric nanogenerators used for wearable electronics. Flexible substrates such as fabrics and mica sheets allow devices to bend comfortably during daily activities. Lead-free ceramics and nanowire structures improve energy conversion, especially at low frequencies from human motion. Examples include ZnO fabric-based nanogenerators producing 8 V and 2.5 μ A from sound vibrations, and gradient PZT ceramics powering 96 LEDs. Curved PZT structures also improved durability. Compared with other energy harvesting methods, piezoelectric systems provide better flexibility and efficiency for wearable sensors and smart textile applications. G. Shi et al. [17]: This study introduced a dual-mode energy harvester that captures ultra-low-frequency human motion using a magnetic up-conversion mechanism. Arc-shaped magnets convert slow movement into higher-frequency vibrations, improving energy generation. The system combines piezoelectric cantilever beams and electromagnetic coils. It achieved a peak power density of 86.3 μ W/cm³ at 2 Hz. The electromagnetic part generated up to 10.65 mW, while the piezoelectric section produced 0.306 mW. A 2200 μ F capacitor was charged to 5.7 V within 18 seconds, proving the system can power small wearable devices and sensors. A. Ali et al. [18]: This survey reviews different piezoelectric energy harvesting techniques that collect power from human body movements such as walking, bending joints, and arm swinging. Materials like PZT, PVDF, and ZnO are compared based on energy output, flexibility, and durability. Various structural designs such as cantilever beams and multilayer structures were analyzed. The results showed that footstep impacts generate the highest energy, sometimes enough to light hundreds of LEDs. However, challenges remain in durability, low-frequency efficiency, and energy storage. The study suggests improving materials and hybrid designs for practical wearable energy systems. G. Selleri et al. [19]: This study developed an energy harvesting system using a stack of 15 PZT ceramic disks to convert mechanical vibrations into electrical energy. The stack produced a maximum output of 13.7 V and 120 μ A current. A bridge rectifier converted the AC output to DC for charging an ionic-liquid supercapacitor. The supercapacitor was charged to 3.1 V in two hours, storing about 110 mJ of energy. This stored energy powered an LED for 120 seconds. The system showed good stability and durability, making it suitable for wearable and low-power electronic devices. G. Shan et al. [20]: This research developed a piezoelectric energy harvester for railway applications to convert track vibrations into electrical energy. The system uses a compression-mode piezoelectric stack, mechanical transformer, and controlled pre-stress to improve efficiency. Laboratory experiments produced a peak power of 511 mW, while field tests on railway tracks reached 568 mW. Average power output was 24.5 mW in the lab and 7.3 mW in real conditions. Plate springs reduced mechanical stress and improved durability. The harvested energy successfully powered wireless railway monitoring sensors without batteries

2.1 Problem statement

In today's modern world, the demand for electricity is increasing rapidly due to the growth of population and technology. Most of the electricity is generated from fossil fuels such as Coal, Oil, and Natural Gas. These resources are limited and also cause environmental problems like air pollution and climate change. At the same time, a large amount of energy from human footsteps in crowded places such as railway stations, shopping malls, schools, and airports is wasted. This project focuses on generating electricity using the Piezoelectric Effect. Piezoelectric Materials produce electrical energy when pressure is applied. By installing piezo tiles in high-traffic areas, the mechanical energy from footsteps can be converted into useful electrical energy for small applications like LED lighting.

III. Methodology

The methodology explains the step-by-step process used to develop the piezo tile energy harvesting system. The main aim is to convert human footsteps into electrical energy using the Piezoelectric Effect. The project begins by identifying the need for renewable energy and reviewing existing research on piezoelectric systems. Suitable Piezoelectric Sensors, electronic components, and storage devices are selected, and the system design is prepared. Piezo sensors are arranged in layers inside the tile. When a person steps on the tile, pressure is applied to the sensors, generating a small amount of electricity. The produced energy is collected through wires, passed through a rectifier and voltage regulator, and stored in a battery. The stored energy is then used to power small devices such as LEDs, demonstrating a simple and eco-friendly method of generating power from human movement.

3.1 Planning:

1. Identify the required components such as piezoelectric sensors, microcontroller (ATmega328), LCD, LEDs, and energy storage elements (battery/supercapacitor).
2. Decide the number and position of piezo sensors needed to collect maximum energy from footsteps.
3. Assemble the circuit by connecting the piezo sensors, electronic components, and the microcontroller.
4. Write and upload the program to the ATmega328 using Arduino IDE.
5. Test the system by applying different foot pressures and observing the voltage and current output
6. Check the performance of the energy storage unit and output devices such as LEDs and mobile charger.

3.2 Technical Specifications:

- Microcontroller: ATmega328
- Programming Language: C (Arduino IDE)
- Sensors: Piezoelectric sensors
- Display: LCD display
- Power Output: suitable for LEDs and mobile charging
- Application: Energy harvesting from footsteps.

IV. Fabrication

The fabrication process for the object in our major project likely involves in several steps:

4.1 Components used

- Piezoelectric Sensors – Convert foot pressure into electrical energy
- ATmega328 Microcontroller – Controls the system and manages output
- Footstep Tile / Base Plate – Supports the piezo sensors and absorbs foot pressure
- LCD Display – Displays generated voltage or system status

- LEDs – Indicate power generation
- Resistors – Limit current and protect components
- Capacitors – Store and smooth generated electrical energy
- Diodes – Convert AC output of piezo sensors to DC
- Wires and Connectors – Used for electrical connections
- Power Supply – Provides required operating voltage

PIEZOELECTRIC SENSORS (PVDF):

Piezoelectric Sensors generate electricity when pressure or force is applied, known as the Piezoelectric Effect. In piezo tiles, footsteps create pressure that produces voltage. Materials like PZT and PVDF are used, and the generated energy is rectified and stored in capacitors or batteries for later use. In the fig-1 shown about the piezoelectric sensor (PVDF).

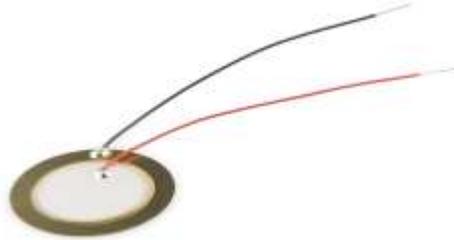


Fig – 1: piezoelectric sensor (PVDF)

FOOTSTEP TILE / BASE PLATE:

The footstep tile is a strong, flat plate placed over Piezoelectric Sensors to evenly distribute foot pressure, ensuring efficient energy generation and protecting sensors. Acrylic is used for its strength and slight flexibility, allowing safe, durable, and long-term operation under continuous footsteps. In the fig-2 shown about the acrylic sheet and a base plate.



Fig-2: acrylic sheet and a base plate

DIODES 1N4007:

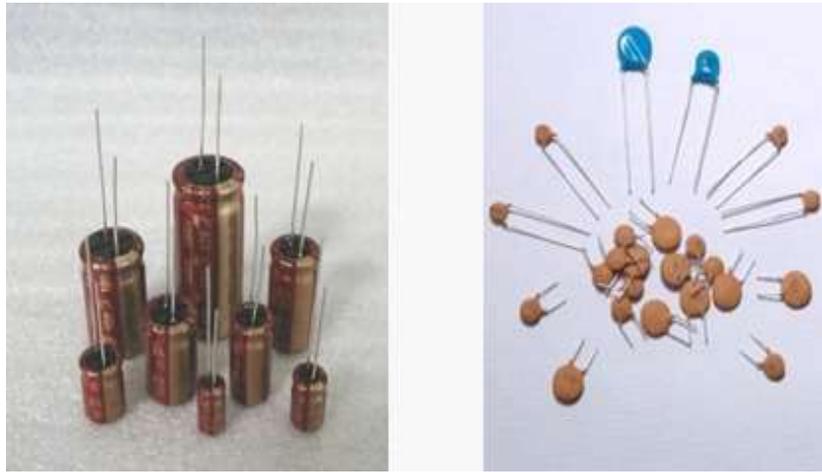
Diodes allow current to flow in one direction, converting the ac generated by piezo sensors into usable dc for storage or devices. They protect circuits from reverse current, enhancing efficiency, safety, and reliability in piezoelectric energy harvesting systems by ensuring proper current flow. In the fig-3 shown about the diodes 1N4007.



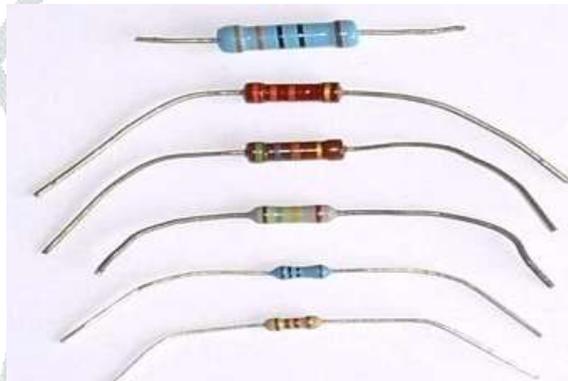
Fig-3: Diodes 1N4007

CAPACITORS 1000 μ F:

A capacitor stores and quickly releases energy from piezo sensors in footstep energy harvesting. It smooths irregular voltage, powers devices like LEDs or sensors, and continues supplying energy briefly when pressure stops, providing fast, temporary storage, voltage stabilization, and protection in the system. In the fig-4 shown about the capacitors 1000 μ F.

Fig-4: capacitors 1000 μ F**RESISTORS 1000k Ω :**

Resistors control and limit current in piezo tile circuits, protecting LEDs, sensors, and microcontrollers from damage. They manage voltage levels, stabilize signals, and reduce fluctuations, ensuring safe, reliable, and efficient operation of the system under varying footstep pressures. In the fig-5 shown about the resistors 1000k Ω .

Fig-5: resistors 1000k Ω **ATMEGA328 MICROCONTROLLER:**

The ATmega328 microcontroller manages the piezo tile system by reading sensor signals, measuring energy, and controlling outputs like LEDs or charging circuits. It monitors voltage, counts footsteps, and optimizes energy use, ensuring efficient operation, component protection, and reliable system performance. In the fig-6 shown about the atmega328 microcontroller.



Fig-6: atmega328 microcontroller

LCD – 016M002B:

An LCD (Liquid Crystal Display) shows information clearly in the piezo tile project. It displays voltage, current, stored energy, and footstep count, helping users monitor energy generation. The LCD uses very little power and easily connects to the ATmega328, improving system monitoring and making the project more user-friendly. In the fig-7 shown about the Liquid crystal display.



Fig-7: liquid crystal display 016M002B

LED RF5A3SWG4-N1:

An led (light emitting diode) produces light when electric current flows through it using electroluminescence. In piezo tile energy harvesting projects, leds act as indicators to show energy generation or storage. they consume little power, produce less heat, and are efficient, reliable, and suitable for low-power applications. . In thefig-8 shown about the light emitting diode RF5A3SWG4-N1.



Fig – 8: light emitting diode RF5A3SWG4-N1

BATTERY (9V):

A battery stores electrical energy and supplies it when needed by converting chemical energy into electricity. In piezo tile systems, it stores energy from footsteps and powers devices continuously. Batteries store more energy than capacitors. Main parts are anode (-), cathode (+), and electrolyte. In the fig-9 shown about the Battery 9v.



Fig-9: Battery 9v

4.2 Fabrication Process:

1. Select a strong base plate for the footstep tile.
2. Fix piezoelectric sensors under the tile with proper spacing.
3. Connect piezo sensors in series or parallel depending on voltage and current requirement.
4. Connect diodes to the sensor output to convert AC to DC.
5. Add capacitors to store and smooth the generated energy.
6. Assemble resistors, LEDs, and other components on a breadboard or PCB.
7. Connect the ATmega328 microcontroller to the circuit.
8. Interface the LCD display with the microcontroller.
9. Upload the program to the microcontroller using Arduino IDE.
10. Test the system by applying foot pressure and checking the output.

4.3 Safety Considerations:

- Ensure all electrical connections are tight and insulated.
- Avoid applying excessive pressure that may damage piezo sensors.
- Handle soldering tools carefully to avoid burns.
- Disconnect power while assembling or modifying the circuit. The fabrication of this mode shown in fig-10.

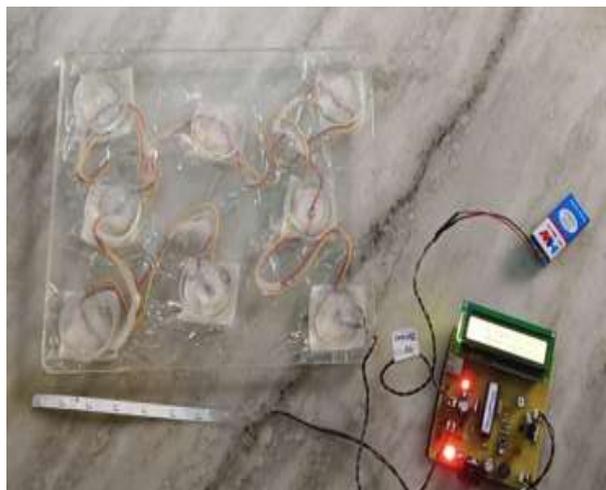


Fig-10: Final Assembly of Piezo tile

V. Result and Discussion:

The result and discussion about the piezo tile for sustainable energy harvesting as follows.

Table 1: Weight vs voltage analysis

Case	Weight	Voltage
1	43	0.14
2	46	0.86
3	52	2.30
4	58	3.74
5	65	5.42
6	70	6.18
7	78	8.54

This table 1 shows how applied weight (force) affects the output voltage produced by the piezo tile. When low weight (43 kg) is applied, voltage is very small (0.14 V). As weight increases, voltage also increases. At 78 kg, the tile produces 8.54 V, which is the highest value.

Table 2: Weight vs power analysis

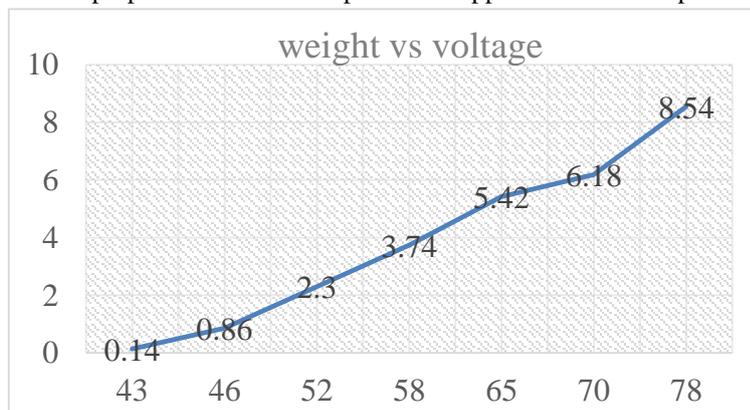
Case	Weight	Power
1	43	0.0000000196
2	46	0.0000007396
3	52	0.00000529
4	58	0.0000139876
5	65	0.0000293764
6	70	0.0000381924
7	78	0.00007296

This table 2 shows how applied weight affects the generated power. Power is very small at low weight. As weight increases, power increases significantly. The maximum power (0.00007296 W) is produced at 78 kg.

Table 3: Weight vs current analysis

Case	Weight	Current
1	43	0.00000014
2	46	0.00000086
3	52	0.0000023
4	58	0.00000374
5	65	0.00000542
6	70	0.00000618
7	78	0.00000854

This table 3 shows the relationship between applied weight (force) and the current generated. At 43 kg, the generated current is very small (0.00000014 A). As the weight increases, the current also increases. At 78 kg, the current reaches 0.00000854 A, which is the highest value. This shows a direct proportional relationship between applied load and output current.



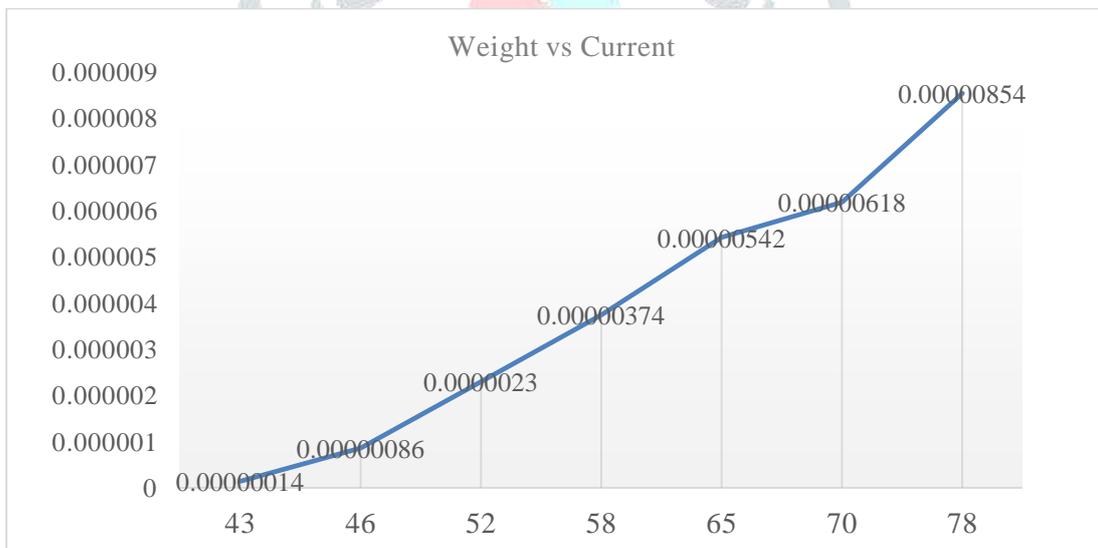
Graph 1: Variation of output voltage with applied load.

This graph 1 shows how variation of output voltage with applied load. The x-axis: weight applied on tile (kg). In the y-axis: output voltage generated (volts). The graph shows a steadily increasing trend. When the applied weight increases, the output voltage also increases. At 43 kg, voltage is very low (0.14 v). At 78 kg, the voltage reaches the maximum value of 8.54 v. The line is almost linear, showing a direct proportional relationship between weight and voltage.



Graph 2: Variation of output power with applied load.

This graph 2 shows how variation of output power with applied load. The x-axis: applied weight (kg). In the y-axis: output power (watts). The graph shows an increasing curve as weight increases. At 43 kg, power is extremely small. As weight increases gradually, power also increases. At 78 kg, the maximum power generated is 0.00007296 w. The graph is slightly curved upward, showing that power increases more rapidly at higher loads.



Graph 3: Variation of output current with applied load.

This graph 3 shows how variation of output current with applied load. The x-axis: applied weight (kg). In the y-axis: output current (amperes). The graph shows a steady increasing trend. At 43 kg, the current is very small. As the applied weight increases, the current gradually increases. The highest current (0.00000854 A) is obtained at 78 kg. The graph is nearly linear, indicating a direct proportional relationship.

Case	Weight(kg)	Voltage(v)	Current(A)	Current(μ A)	Power(w)
1	43	0.14	0.00000014	0.14 μ A	0.0000000196
2	46	0.86	0.00000086	0.86 μ A	0.0000007396
3	52	2.30	0.0000023	2.30 μ A	0.00000529
4	58	3.74	0.00000374	3.74 μ A	0.0000139876
5	65	5.42	0.00000542	5.42 μ A	0.0000293764
6	70	6.18	0.00000618	6.18 μ A	0.0000381924
7	78	8.54	0.00000854	8.54 μ A	0.00007296

Table 4: Piezo tile output calculations for different weights.

When a person steps on the piezo tile, mechanical pressure is applied.

This pressure produces electrical voltage.

As the weight increases, the generated voltage increases.

Using a resistance of 1 M Ω , current is calculated.

Power is calculated using voltage and current.

The power generated is very small, but useful for low-power applications.

Maximum voltage obtained: 8.54 V

Maximum power obtained: 0.072 mW

Piezo tiles are suitable for low-power sustainable energy generation. In the table 4 piezo tile output calculations for different weights.

VI. Conclusion:

The piezo tile project demonstrates conversion of mechanical energy into electrical energy using piezoelectric materials. Experimental results show that as applied weight increases, the generated voltage, current, and power also increase, reaching maximum values at 78 kg. When a person steps on the tile, compression of the piezo material produces electrical charges. Although the output power is in the micro range, it can be stored in capacitors or batteries and used for low-power devices like LEDs and sensors. The system is eco-friendly and suitable for crowded places such as railway stations, malls, airports, colleges, and walkways.

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