A Socially Relevant Project Report

On

SUSTAINABLE PEDESTRIAN CROSSING AND TRAFFIC LIGHTS SYSTEM USING PIEZOELECTRIC ROADS

Submitted in partial fulfilment of the requirement for the award of

BACHELOR OF TECHNOLOGY
in
CIVIL ENGINEERING

Submitted by

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Under the Guidance of

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SREE VIDYANIKETHAN Engineering College (Autonomous)

Department of Civil Engineering
SREE VIDYANIKETHAN ENGINEERING COLLEGE
(AUTONOMOUS)

(Affiliated to JNTUA, Ananthapur, approved by AICTE, New Delhi, Accredited by NBA and NAAC 'A+')
Sree Sainath Nagar, A. Rangampet, Tirupati, Andhra Pradesh – 517102

2022

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DEPARTMENT OF CIVIL ENGINEERING

Certificate

This is to certify that the socially relevant project report entitled

SUSTAINABLE PEDESTRIAN CROSSING AND TRAFFIC LIGHTS SYSTEM USING PIEZOELECTRIC ROADS

is the bonafide work done and submitted by

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in the **Department of Civil Engineering, Sree Vidyanikethan Engineering College, Autonomous,** A. Rangampet, in partial fulfilment of the requirements for the award of the degree of **Bachelor of Technology in Civil Engineering** during the academic year 2021-2022.

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Submitted for III B.Tech. II Semester socially relevant project held on ....at Sree Vidyanikethan Engineering College, A.Rangampet, Tirupati.

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(Senior Faculty)

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ABSTRACT

In suburban Non-Light and Light control areas crosswalk lacks traffic lights to manage traffic order, people, and traffic flow the traditional traffic equipment has very limited warning capabilities that can't satisfy the safety need. Drivers can not prejudge there will be pedestrians crossing the crosswalk ahead, and pedestrians lack traffic safety awareness, which easily causes crosswalk accidents and power outages are pretty common as a result traffic lights won't work in times of need to control the traffic flow. Besides the vertical vibrations created by the vehicular traffic are released into the atmosphere as thermal energy which is being wasted. Nevertheless, a smart pedestrian crosswalk and traffic lights system that runs on a continuous power supply can be a possible solution to the problem by which crosswalk accidents and traffic lights power outages can be minimized. In connection to that, this project aims to devise a method and equipment that can not only supply continuous power but supply Sustainable energy that is produced by vehicular traffic on Piezoelectric road surfaces that harvest the mechanical energy produced by vehicles on the road surface and converts them into electrical energy with the help of generators. This electrical energy is charged into the lithium-ion batteries and is used to continuously supply power to the traffic lights and crosswalks for the crossing of pedestrians. To conclude, the implementation of these piezoelectric roads in suburban areas can be a feasible solution to decrease crosswalk accidents and to manage the traffic flow without any power outages.

Keywords: Smart Pedestrian Crosswalk, Sustainable Energy, Piezoelectric Roads, Traffic Flow, Traffic Lights

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1. INTRODUCTION

1.1 GENERAL

Electricity has become a lifeline of present-day civilization and thus its demand is enormous and is growing steadily. There seems no end to the different ways one can generate pollution-free electricity. On one hand, rising concern about the gap between demand and supply of electricity for the masses has highlighted the exploration of alternate sources of energy and their sustainable use. On the other hand, traffic on the road all over the world is increasing day by day thus; congestion on roads is becoming inevitable with the fancy of masses toward personal transportation system for their growing mobility. Energy demand and heavy traffic correlation motivate to dream about the road that would harvest energy from the vehicles driving over it. For this, piezoelectric material embedded beneath a road, the piezo-smart road, can provide the magic of converting pressure exerted by the moving vehicles into electric current.

The system is based on piezoelectricity, which uses pads of metallic crystals buried beneath roads to generate electricity when put under the pressure of quickly moving traffic. With the technology, now, engineers are poised to harvest some of the spare energy of the world's moving vehicles. When a vehicle drives over the road it takes the vertical force and compresses the piezoelectric material, thereby generating electricity.

1.2 SCOPE OF THE PROJECT

The utilization of energy is an indication of the growth of a nation. For example, the per capita energy consumption in the USA is 9000 KWh per year, whereas the consumption in India is 1200 KWh. One might conclude that to be materially rich and prosperous, a human being needs to consume more and more energy. A survey on the energy consumption in India published a pathetic report that 85,000 villages in India do not still have electricity. The supply of power in most parts of the country is poor. Hence more research and development and commercialization of technologies are needed in this field. India, unlike the top developed countries, has very poor roads. Talking about a particular road itself includes a number of speed breakers. By just placing a unit like the "Power Generation Unit from Speed Breakers", so much energy can be tapped. This energy can be used for the lights on either side of the roads and thus much power that is consumed by these lights can be utilized to send power to these villages.

1.3 PIEZOELECTRICITY AND PIEZOELECTRIC EFFECT

The word piezoelectricity means electricity resulting from pressure. It is derived from Greek piezo or piezein, which means to squeeze or press, an electric or electron, which stands for amber, an ancient source of electric charge. Piezoelectricity was discovered in 1880 by French physicists Jacques and Pierre Curie. The piezoelectric effect is understood as the linear electro-mechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry (notably crystals, certain ceramics, and biological matter such as bone, DNA, and various proteins). The piezoelectric effect is the reversible process in that materials exhibiting the direct reverse piezoelectric effect (the internal generation of the electrical charge resulting from an applied mechanical force) also exhibit the reverse piezoelectric effect (the internal generation of the mechanical strain resulting from an applied electrical field).

1.4 PIEZOELECTRIC ROADS

1. The roads which produce electricity by application of mechanical energy when a vehicle moves over the road, those roads are called piezoelectric roads.
2. These roads are having a piezoelectric sensor within them to produce electricity.
3. This kind of construction is built in Israel, California and we are trying to construct it here in India.

1.5 CONSTRUCTION OF PIEZOELECTRIC ROADS

1. The first layer is laid with fine gravel and sand content.
2. Then a thin layer of asphalt is laid which acts as a strong base for the generators.
3. Piezoelectric generators are placed in quick-drying concrete as per the design and left for 30 min.
4. Then all the generators are wired in series to get collective output.
5. A bitumen sheet is used to cover all the generators to provide better adhesion of concrete to asphalt.
6. Finally a thick layer of asphalt is laid which finishes the construction.

1.6 HARVESTING MECHANISM

1. Generators harvest the mechanical energy of the vehicles and convert to electrical energy.
2. Electric energy is transferred and stored via a harvesting module. Then it is charged into the battery on one side of the road.
3. From there it is distributed.
4. Yield: For 1 km of the piezoelectric road of one lane we can generate 44000KWh per year.

2. LITERATURE REVIEW

2.1 GENERAL

In the previous chapter, the definition and construction of the Piezoelectric road system were discussed. In this Present chapter, the reviews of different literatures are discussed

2.2 LITERATURE REVIEW

Priya. S., et.al., (2005) Modeling of electric energy harvesting using piezoelectric windmill Appl. Phys. Lett. 8718 2005 184101-184101-3 This letter reports a theoretical model for the determination of generated electric power from piezoelectric bimorph transducer low-frequency energy range far from the piezoelectric resonance. The model is divided into two parts. In the first part, the open-circuit voltage response of the transducer under the ac stress is computed based on the bending beam theory for bimorph. In the second part, this open circuit voltage acts as the input to the equivalent circuit of the capacitor connected across a purely resistive load. The results of the theoretical model were verified by comparing it with the measured response of a prototype windmill. The prototype piezoelectric windmill consisting of ten piezoelectric bimorph transducers was operated at the wind speed of 1–12 mph. A power of 7.5 mW at the wind speed of 10 mph was measured across a matching load of 6.7kΩ6.7kΩ. The theoretical model was found to give a very accurate prediction of the generated power and matching load and an excellent matching was found with the experimental results.

Xinchun Guan, Yanchang Liu, Hui Li, Jinping Ou et.al., (2010) Study on Preparation and properties of 1–3 cement-based piezoelectric composites J. Disaster Prevent. Mitigat. Eng., 30 (S1) (2010), pp. 345-347 In this study, cement-based piezoelectric composites have been prepared from Portland cement with the addition of 70 vol.% of PZT powders and various amounts of modified CNTs ranging from 0 to 1.3 vol.%. The CNTs act as a conductive filler dispersed in the cement matrix, improving the poling efficiency of the composites and enabling the polling process to be carried out at room temperature, in contrast to the 120 °C required for the PZT/cement composites without CNTs. The addition of CNTs significantly enhanced the piezoelectric properties of the composites. With a CNT content of 0.3 vol.%, the CNTs/PZT/cement composite showed the highest piezoelectric strain factors (d_{33}) of 62 pC/N and piezoelectric voltage factors (g_{33}) 60×10^{-3} Vm/N, which are the promising characteristics for its potential use in the smart civil engineering structures.

Zhao Hong-duo, Liang Ying-hui, Ling Jian-ming et.al., (2011) Study on harvesting energy from pavement based on piezoelectric effects J. Shanghai Jiaotong Univ, 45 (S) (2011), p. 62 This article demonstrates the design of a road piezoelectric transducer (PZT) through a laboratory load test, to utilize the load mechanical energy in road. PZT-5H was selected as the piezoelectric vibrator material. With the combination of the action property of low-frequency forced vibration of the pavement vehicle wheel load, a simple supported disk lap piling piezoelectric vibrator was used as the core component of the road piezoelectricity generating set. The tracking wheel-pressure test of a beam piece was used to determine the piezoelectricity generating capacity of road pavement. The maximum voltage that could be reached is 65.2 V. The primary wheel rolling impact could produce an electric energy of 0.23 mJ. The electric capacity of 0.8 kW/h could be produced per day, which can meet the demand of signal lights.

Haocheng Xiong, Linbing Wang, Dong Wang, Druta Cristian et.al., (2012) Piezoelectric energy harvesting from traffic induced deformation of pavements Int. J. Pavement Res. Technol., 5 (5) (2012), p. 333 In the last decade, the sensing technology and the concern about the robustness of the roadways have significantly grown. The limit of power source has become an impediment force of the research of sensing technology. Recently, energy harvesting is more proven as a promotive solution. It also provides a new source of clean and renewable energy that can help reduce negative environmental impacts while contributing to improving roadway mobility. In this work, four common energy harvesting approaches are compared and piezoelectric energy harvesting is proposed. It is known as a stable technology converting kinetic energy into electricity. The sinusoidal energy power output from the random external excitation would be rectified and stored by an interfacial circuit. Lead Zirconate Titanate (PZT) is widely used in piezoelectric energy harvesting systems due to its high cost-effectiveness. This work presents a maneuver for powering the transportation infrastructural facilities and monitoring electronics using piezoelectric energy harvesting technology. Comparison of coupling configuration, material selection, and testing methodologies are also presented

Yuan Tianchen, Yang Jian, Song Ruigang, Liu Xiaowei et.al., (2014) Vibration energy harvesting system for railroad safety based on running vehicles Smart Mater. Struct., 23 (12) (2014) This research is focused on energy harvesting from track vibration in order to provide power for the wireless sensors which monitor railroad health. Considering that track vibration has vibration energy, a new method is proposed in the paper to harvest energy based on the piezoelectric effect. The piezoelectric generator called drum transducer is the key part for tracking vibration energy harvesting. The model of the drum transducer is established and the simulation results show that it can generate 100 mW in real track situations. In addition, an experiment rig is developed and its vibration model is also established. The simulation and experiment results show that the peak open-circuit voltage of the piezoelectric generator is about 50–70 V at the full load of the train. The whole track vibration energy harvesting system is analytically modeled, numerically simulated, and experimentally realized to demonstrate the feasibility and the reliability of the theoretical model. This paper is the theoretical basis of harvesting, recovering, and recycling the track vibration energy for track safety.

Zhang. Y., Cai. S.C.S., Deng. L., et.al., (2013) Piezoelectric-based energy harvesting in bridge systems J. Intelligent Mater. Syst. Struct., 25 (12) (2013), pp. 1414-1428 The piezoelectric-based energy harvesting on civil infrastructures. Piezoelectric cantilever–based harvesters are adopted considering their wide usage. Four concrete slab-on-girder bridges that represent the majority of bridges in the United States are used as the platforms for the energy harvesting. In the simulation, the distributed-parameter model is used for the energy harvester, while four three-dimensional bridges with HS20-44 truck models are developed using ANSYS and MATLAB. Two scenarios for the bridge–vehicle systems are simulated: bridges with only one passing vehicle and bridges with a continuous vehicle flow. A parametric study is carried out to study the effect of various properties of the bridge and vehicle on energy harvesting. The simulation result shows that the energy output power increases with poorer road conditions and smaller bridge span lengths. Optimal vehicle speeds and energy harvester positions are also investigated and discussed in this article.

Hou. Y., Guo. M., Ge. G., Sun. M., et.al., (2017) Mixed-Mode I-II cracking characterization of mortar using phase-field method J. Eng. Mech., 143 (7) (2017) There have been many studies on mortar single-mode cracking behavior under tensile loading, however, the mixed-mode cracking is still not fully understood. In this paper, the mortar Mixed-Mode I–II cracking behavior is investigated by decomposing the total fracture energy into Mode I component and Mode II component. The total fracture energy is then put into the modified nonconserved Allen–Cahn equation to simulate the cracking process. Two types of cracking experiments, namely, internal inclined cracking test and single-edge cracking test, are conducted to verify the simulation results. It is discovered that the phase-field method simulation could satisfactorily capture the Mixed-Mode I–II cracking behavior of mortar.

Hou. Y., Wang. L., Wang. D., Liu. P., et.al., (2017) Characterization of bitumen micro-mechanical behaviors using AFM phase dynamics theory and MD simulation Materials, 10 (2) (2017), Fundamental understanding of micro-mechanical behaviors in bitumen, including phase separation, micro-friction, micro-abrasion, etc., can help the pavement engineers better understand the bitumen mechanical performances at macroscale. Recent researches show that the microstructure evolution in bitumen will directly affect its surface structure and micro-mechanical performance. In this study, the bitumen microstructure and micro-mechanical behaviors are studied using Atomic Force Microscopy (AFM) experiments, Phase Dynamics Theory and

Molecular Dynamics (MD) Simulation. The AFM experiment results show that different phase-structure will occur at the surface of the bitumen samples under certain thermodynamic conditions at microscale. The phenomenon can be explained using the phase dynamics theory, where the effects of stability parameter and temperature on bitumen microstructure and micro-mechanical behavior are studied combined with MD Simulation. Simulation results show that the saturates phase, in contrast to the naphthene aromatics phase, plays a major role in bitumen micro-mechanical behavior. A high stress zone occurs at the interface between the saturates phase and the naphthene aromatics phase, which may form discontinuities that further affect the bitumen frictional performance.

Yoshiyasu Takefuji., et.al., (2008) Known and unknown phenomena of nonlinear behaviors in the power harvesting mat and the transverse wave speaker, in: Proceedings of Inter-national Symposium on Nonlinear Theory and Its Applications. Budapest, Republic of Hungary, 2008. The power harvesting project is mentioned where the power generation mat using piezoelectric elements was experimented and demonstrated in Tokyo station of Japan Railways east (JR-east) company in 2006 and 2008 respectively. The commuters and passengers generate electric power by passing the power generation mats through SUICA (RFID) gates which can provide enough electric power for operating the RFID gate system. The system is composed of the power generation circuit and the super capacitor circuit to store the generated electric power. Thermoelectric power generation project is also proposed in this paper where peltier elements are used for generating the continuous power harvesting. Unknown phenomena of the transverse acoustic waves from a new speaker are depicted in this paper. The new speaker under development is useful in railways stations and trains where we can hear the transverse acoustic sound clearly in noisy places. The transverse wave speaker does not generate reverberant sound and the sound attenuation in distance is much smaller than 6dB.

3. METHODOLOGY

3.1 COMPONENTS REQUIRED

1. PIEZOELECTRIC SENSOR

A sensor which works on the principle of piezoelectricity is known as a piezoelectric sensor. Where piezoelectricity is a phenomenon where electricity is generated if mechanical stress is applied to a material. Not all materials have piezoelectric characteristics. There are various types of piezoelectric materials. Examples of piezoelectric materials are natural available single-crystal quartz, bone, etc… Artificially manufactured like PZT ceramic etc…

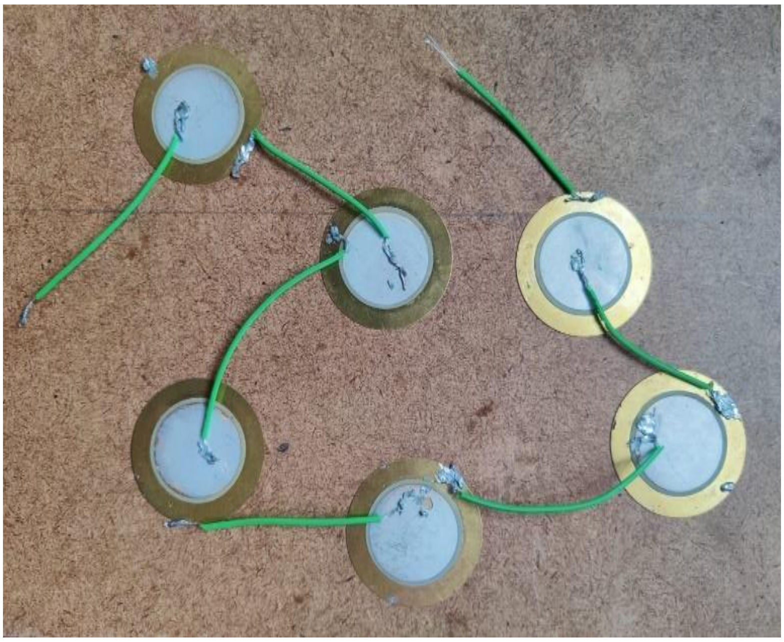

Fig 3.1: Piezoelectric Sensor

2. LED LIGHT

LED stands for light-emitting diode. LED lighting products produce light up to 90% more efficiently than incandescent light bulbs. How do they work? An electrical current passes through a microchip, which illuminates the tiny light sources we call LEDs and the result is visible light. To prevent performance issues, the heat LEDs produce is absorbed into a heat sink.

Fig 3.2: LED Light

3. RESISTOR

A resistor is an electrical component that limits or regulates the flow of electrical current in an electronic circuit. Resistors can also be used to provide a specific voltage for an active device such as a transistor.

Fig 3.3: Resistor

4. BATTERY

Hi-Watt 9V Battery is the most commonly used and portable 9V battery. It is non-rechargeable and is a high-capacity and low-cost solution for many electronic devices. It is based on Zinc Carbon Chemistry and can be used and easily replaced if discharged just like any standard AA and AAA batteries. The battery can be used to power LEDs, Toys, flashlights and Torch, electronic equipment like multimeter, wall clocks, or other devices with a 9V system. A battery snap connector is generally used to connect it with a breadboard.

Fig 3.4: Battery

5. CONNECTION WIRES

1. The conducting wire is a component of a circuit that carries the current in the circuit. It is made out of a current-conducting material like copper or tungsten.2. The wire is covered by an insulating material like rubber for protection as well as to avoid loss of current.

3. Conducting wires are represented by different colors in a circuit to distinguish their function. Green is for grounding wire, black is for neutral, and red usually is for the live wire.

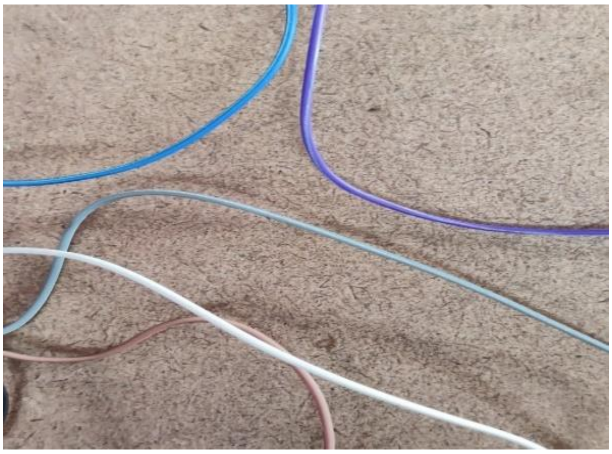

Fig 3.5: Connection Wires

6. ELECTRIC SWITCH

An electric switch, a device for opening and closing electrical circuits under normal load conditions, is usually operated manually. There are many designs of switches; a common type—the toggle, or tumbler, switch—is widely used in home lighting and other applications. The so-called mercury, or "silent," switch is used extensively for controlling home lighting circuits. The oil switch has its live parts immersed in oil to reduce arcing. The aggregate of switching or circuit-breaking equipment for a power station or a transforming station, frequently located in an outdoor yard (switchyard) beside the station, is usually regarded as switchgear.

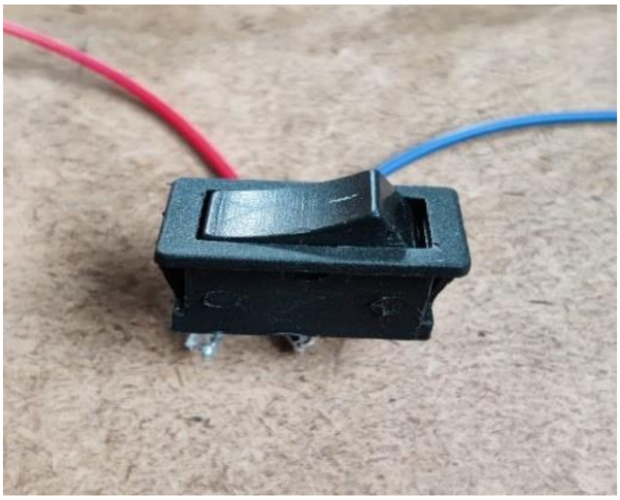

Fig 3.6: Electric Switch

3.2 WORKING PRINCIPLE OF PIEZOELECTRIC ROADS

Piezoelectricity is the electricity generated because of the application of mechanical stress on certain materials, such as crystals (Quartz), ceramics (Lead Zirconate Titanate), and even some biological material such as bone and DNA.

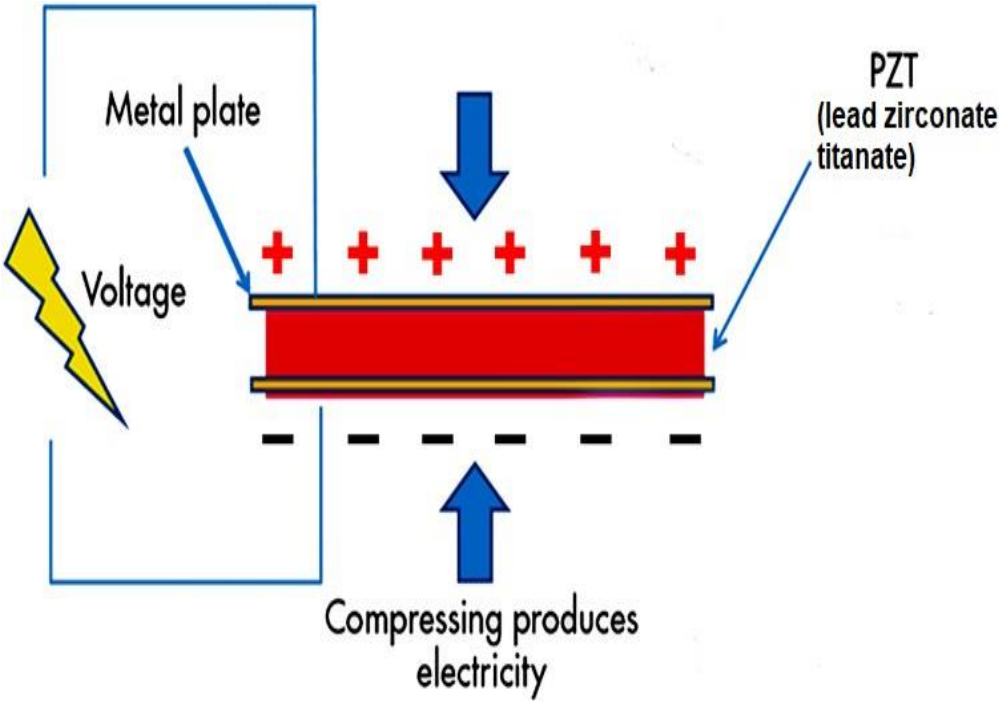

Fig 3.7: Working of Piezoelectric Road

- The actual mechanism involves the generation of electric dipoles, which are two opposite charges separated by a small distance, which can be loosely compared to a bar magnet in the crystal structure.
- When a force is applied to the crystal, small changes in the structure of the crystal lattice induce the formation of an electric dipole, which in turn produces a voltage across the faces of the crystal.
- This voltage makes available a small amount of charge that can be used to power an external circuit. This effect also works in reverse, a voltage applied to a piezoelectric element will result in it deforming along a plane. This is how piezo buzzers and ultrasonic transducers work.
- Let us look at a common piezoelectric material, quartz, in detail.

- Quartz is a crystalline form of the compound silicon dioxide, which has a single silicon atom surrounded by four oxygen atoms arranged in a hexagonal pattern. Normally, each vertex of the hexagon has single oxygen or silicon atom in alternating order.

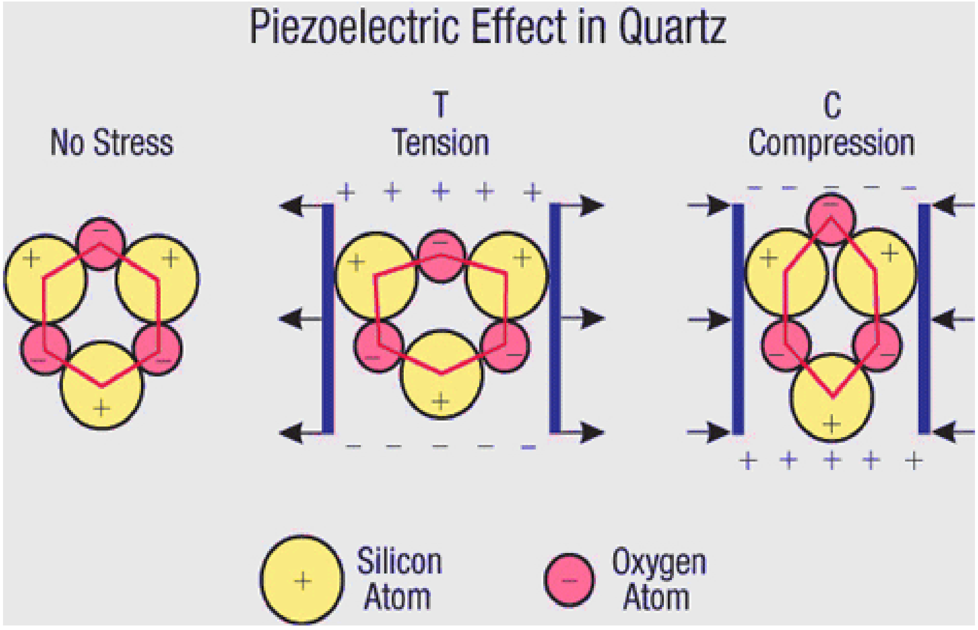

Fig 3.8: Piezoelectric Effect in Quartz

- Each atom carries with it a small charge. In the case of quartz, the oxygen atom carries a negative charge, and the silicon atom a positive charge. Since the atoms are all arranged at an equal distance from each other, the charges are balanced on each vertex and there is no net dipole moment.
- When the crystal is deformed along two opposite sides of the hexagon, the structure is flatted and now the distance between opposite vertices increases at the ends. This causes an imbalance of charges along a central axis, creating a small dipole moment.
- This dipole moment induces a small voltage across the crystal perpendicular to the applied force

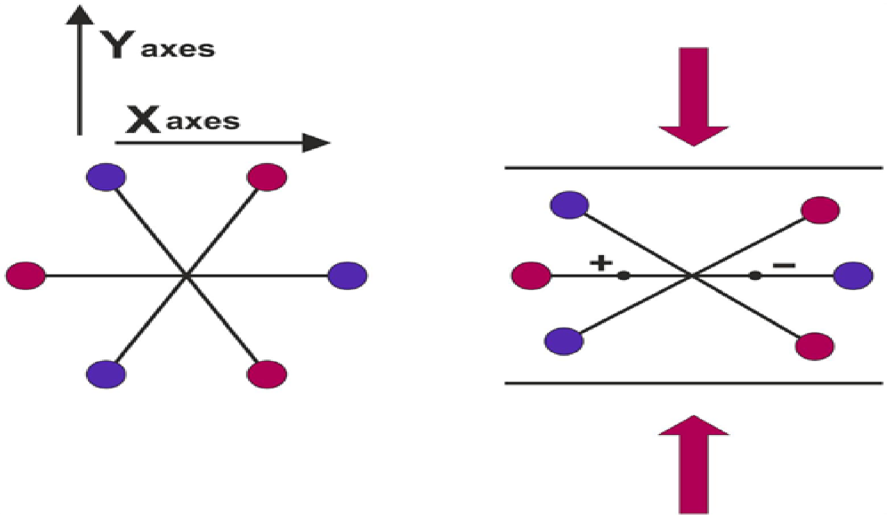

Fig 3.9: Dipole Moment

Only part of the energy from the fuel combustion of the vehicle is used for moving the car along the road or run useful accessories, such as air conditioning. The rest of the energy is lost to engine inefficiencies. The energy expended on the vehicle's movement is mainly used to overcome rolling resistance, resistance occurring when the wheel is moving forward on the road surface. In addition to the energy used to move the wheel forward (in the horizontal direction), part of the fuel combustion is wasted on creating a deformation in the asphalt, which is basically the product of the loaded wheel's influence on the road surface. A typical asphalt road can be described as a visco-elastoplastic material, with elasticity being its dominant material characteristic. When a vehicle passes over a road, the road deflects vertically. The deflection is proportional to the weight of the vehicle and the asphalt stiffness. The only source for harvesting electric energy is this part of mechanical energy related to the asphalt vertical deformation, which is a percentage from the total energy of the vehicle (energy of the fuel combustion). It is known that the vertical load of the vehicle's wheels yields compression stress, diminishing with depth. Piezoelectric generators are embedded at a depth of about 5 cm; the area where the compressions stress is maximal. The external load results in the deformation in both the asphalt layer covering the generators and the generators, similar to the typical deformation in a piezoelectric column loaded under axial load. The deformation of the generator and the shortening of the piezoelectric columns embedded in the generators, generate charges on the piezoelectric columns that are the source for the electric energy. The energy needed to deform the road is a function of various parameters such as: the surface quality of the road, asphalt type, environment temperature and others.

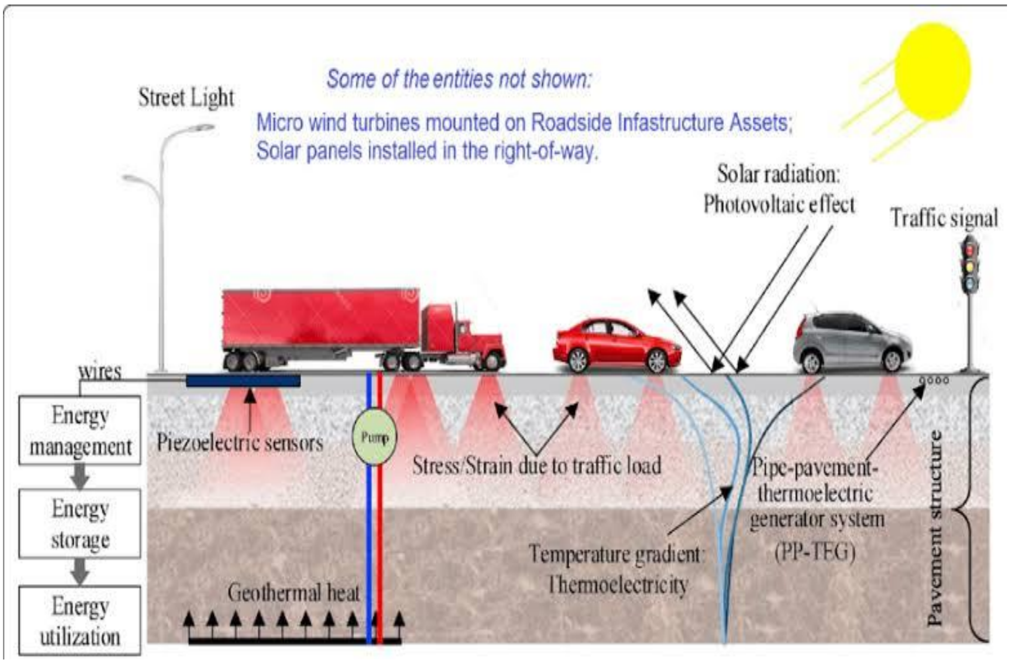

Fig 3.10: Technologies that can turn roads and bridges into “power plants”

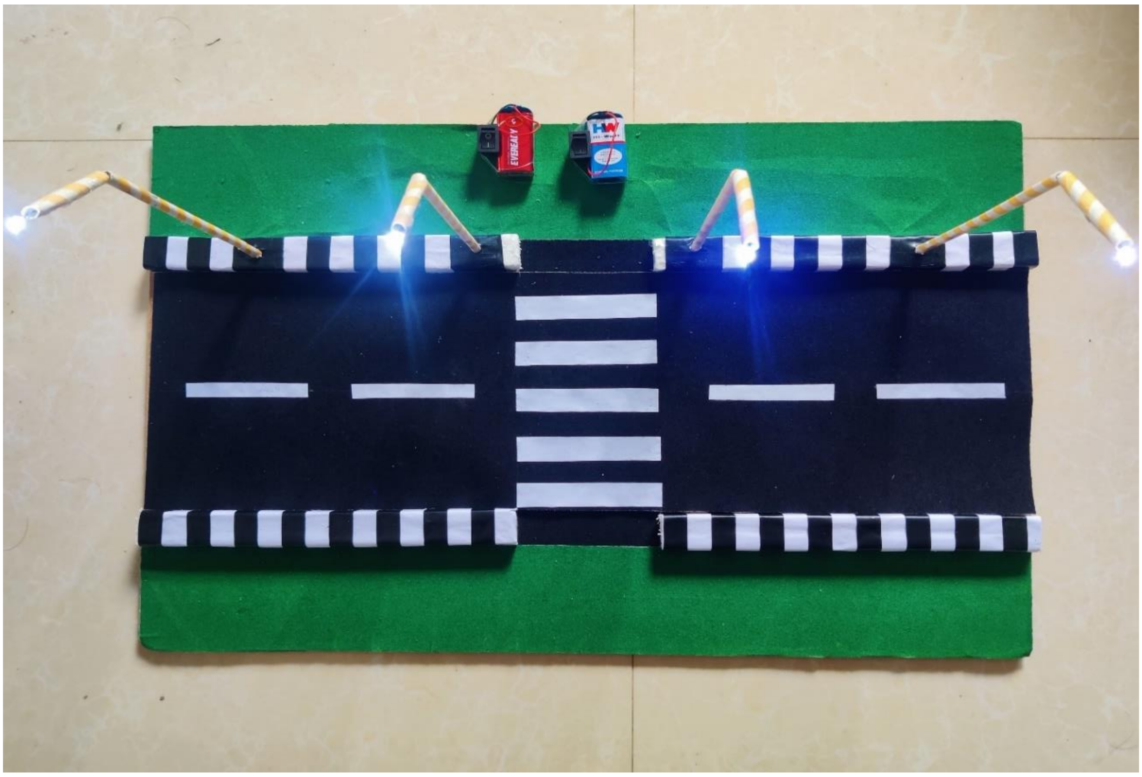

Fig 3.11: Model image for Piezoelectric Road

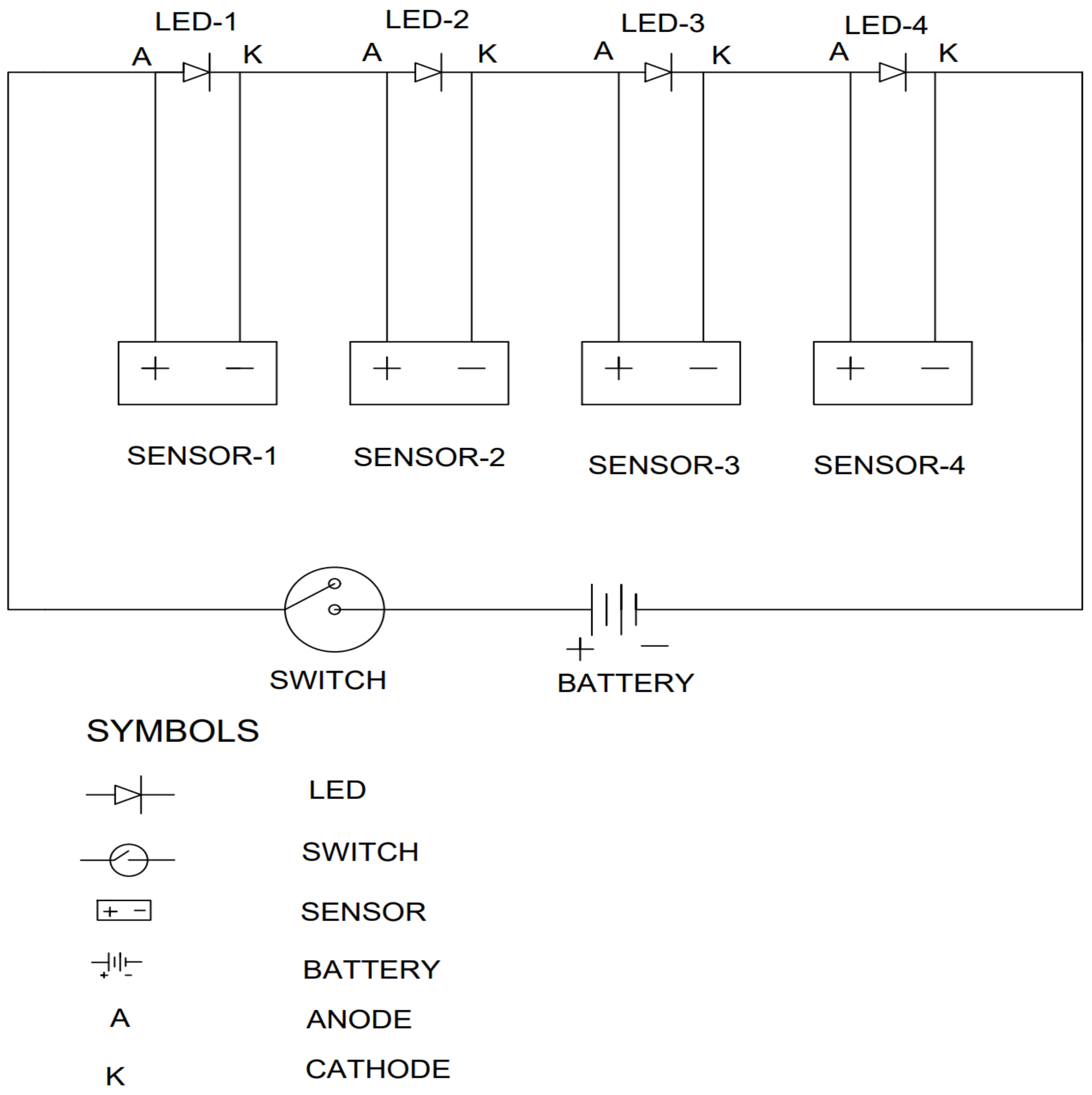

Fig 3.12: Circuit Diagram for Piezoelectric Road

3.4 ADVANTAGES OF PIEZOELECTRIC ROADS

- Movement of vehicles are mostly constant on busy roads and so constant power can be produced.
- The power generated is this concept is green power and so there is no harm on the environment.
- This power can be used for street lights and small scale purposes.
- The response is very fast. Even the remote area can be easily electrified.
- It is very easy to control small displacement with the applied voltages.

3.5 DIS-ADVANTAGES OF PIEZOELECTRIC ROADS

- It exhibits high Hysterisis and creep.
- High electric field may lead to breakdown and failure.
- Maintenance of roads is difficult and constant inspections are to be made.

3.6 USES OF PIEZOELECTRICITY

All the electrical devices nowadays are just not limited to electrical connection in between them but have this piezoelectricity as a common thing in all applications. Cell phones, diesel fuel injectors, grill igniters, ultrasonic transducers, acoustic guitar pickups, vibration sensors, and musical greeting cards etc. utilises piezoelectricity. The additional development of manmade piezo materials which includes piezoelectric ceramics.

The Uses of piezoelectricity includes the following fields:

- Piezoelectric Motors
- Actuators in Industrial Sector
- Sensors in Medical Sector
- Instrument pick-ups
- Microphones

3.6 CONCLUSION

The development of the Internet of Things concept, wearables devices, and wireless technologies has led to the need for self-powered systems due to the inaccessibility of batteries for changing. A solution for these self-powered systems is to harvest mechanical energy using piezoelectricity. Piezoelectric materials have the property to generate an electric field when a mechanical force is applied. This phenomenon is known as the direct piezoelectric effect. Piezoelectric energy harvesting has several advantages, such as high energy and power density, low cost, good scalability, and ease of application. However, due to its main disadvantages (low level of harvested power and the need for rectification, maximum power extraction, and output voltage regulation), piezoelectric transducers cannot be used alone to harvest mechanical energy. Therefore, a piezoelectric energy harvester usually contains an AC-DC converter, has a two-stage conversion circuit, or uses non-linear techniques such as SSHI or SECE. The piezoelectric energy harvesting technique can be used in a multitude of applications; therefore, each implementation needs to optimize the technique for its own needs. First, a suitable transducer must be found. Piezoelectric transducers can be found in different shapes (cantilever beam, circular diaphragm, cymbal type, stack type, and more) and can be made from different materials, each with its own characteristics. When the piezoelectric transducer is chosen, the next step is to develop a model in order to simulate and optimize the behavior in the integrated system.

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