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Research Paper

Application of Piezoelectric Road on Queen's Necklace Road, Marine Drive

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ABSTRACT: *Electricity is a basic need for everyone in their daily life. However, in India only 65% of the entire population are able to use these electricity and rest 35% still live in darkness. That 65% population also doesn't get continuous power supply and still face power cuts. On coastal areas the asphalt roads(Tar road) are used widely. Upon these roads thousands of vehicles run on it and the road deflects vertically(vibrates).By incorporating piezoelectric generators in the roads we can convert the vibrations caused by the vehicles into useful electricity. The Marine Drive, Queen's Necklace Road is a 3 kilometer-long Promenade along the Netaji Subhash Chandra Bose Road in Mumbai, India. The road and promenade were constructed by Pallonji Mistry. It is a banana-shaped, six-lane concrete road along the coast of a natural bay. Our project aimed at generation of electricity through vibrations occurs due to vehicle traffic.*
***KEYWORDS:* piezoelectric generators, electricity, vibrations, roads, India, Marine Drive, vehicles.**

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I. INTRODUCTION

Piezoelectricity was present ever since mid-18th century. The prefix piezo is a Greek word which means 'press' or 'squeeze'. A piezoelectric substance is one that produces an electric charge when a mechanical stress is applied (the substance is squeezed or stretched). Piezoelectricity is the electric charge that accumulates in certain solid materials (such as crystals, certain ceramics, and biological matter such as bone, DNA and various proteins) in response to applied mechanical stress. The word piezoelectricity means electricity resulting from pressure and latent heat. The first experimental demonstration of a connection between macroscopic piezoelectric phenomena and crystallographic structure was published in 1880 by Pierre and Jacques Curie.

Researchers have studied the piezoelectric energy harvesting technology for numerous years. In 2005, Priya invented a pocket-sized piezoelectric windmill that can be attached to a rotating cam. As the cam rotates, the piezoelectric material is activated and converts mechanical energy into electric energy. [1].

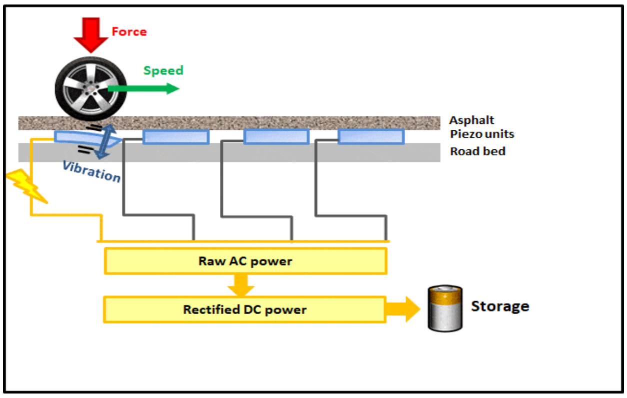
Thermo-electric, electromagnetic, photovoltaic and piezoelectric technologies are the four energy extraction technologies that attract the most attention among energy conversion technologies. However, energy formed from various objects in motion, vibration machines or any other source of mechanical energy is not being captured. Therefore, this source of energy is dispersed and thus wasted. As an effective method to utilize this loss, piezoelectric materials are used to absorb the wasted mechanical energy and convert it to electrical energy.

Here, a plan is made for electrification of street lights using piezoelectric sensors. It can generate enough electricity for consumption by street lights where any other power source is not available. At first, the connected serially. The electrical energy is reused for charging of the battery. When vehicles will pass over the crystal, mechanical stress will be produced which in turn will generate an AC voltage.

II. PIEZOELECTRIC ROADS

The roads that generate electricity as the vehicle passes across the road by adding mechanical energy are called as piezoelectric roads. To generate energy these roads have a piezoelectric sensor within them. This style of construction is being constructed in Israel, California and people are attempting to develop it here in India.

The structure comprises of a slight box around the piezoelectric material, which is set underneath the black-top layer. As the truck ignore the plates inserted in black-top layer, they pack a tank filled of water powered liquid under the street, which thusly makes a progression of siphoning activity that turns a generator to deliver electricity. When a vehicle rolls over the container, it takes the vertical power and packs the piezoelectric material in this manner producing power. The vitality 80kWph kilometer of street for traffic-can be put away in close by battery or super capacitor, contingent on the application or sent legitimately to road lights and other street side devices. The movement of vehicles on the road results in a conversion of vitality into power through piezoelectric impact. This source of energy is, unfortunately, mostly wasted as heat when the road bends under the weight of the vehicle. However, by replacing the road material with a stiffer layer of piezoelectric material, even a small amount of energy can be saved. [2].



Working of Pizeoelectic Road

III. LITERATURE SURVEY

This review presents the important applications of piezoelectric materials in civil engineering in recent years. Piezoelectric materials have attracted attention in many civil engineering applications, as a result of their capability of generating electrical power when subjected to a mechanical stress, or of generating mechanical stress when subjected to an electric field.[3]

This article aims to assess the functionality of piezoelectricity in roads to utilise energy executed from the moving vehicles. The energy is converted into electrical energy using piezoelectric technology to replace fossil fuel in streetlight applications. The vitality of this technology arises as fossil fuels is being over consumed which makes it challenging to provide sufficient power in the next era as an effect of growing population. Being dependent on renewable energy to account for a greater global consumption level is essential to overcome the risks associated with fossil fuels. Piezoelectric road is a new energy evolution to provide a sustainable solution in terms of environment, economy, and social needs.[4]

Piezoelectric energy harvesting is an efficient technique among energy scavenging methods employed in asphalt pavements. Several designs are reported in the literature; however, what is less discussed is how to design the harvester. In this paper, a fixed volume of piezoelectric material is considered, and various design parameters are discussed in order to achieve an improved design. The main objective is to enhance the harvester performance, considering electrical and mechanical aspects, simultaneously. The output power, the level of induced stress on the piezoelectric material, the endurance limit, and the coupling effect of the device with the pavement are considered. [5]

This review presents the important applications of piezoelectric materials in civil engineering in recent years. Studies on the development of smart construction structures have been carried out by using materials such as piezoelectric materials around the world. Piezoelectric materials have attracted attention in many civil engineering applications, as a result of their capability of generating electrical power when subjected to a mechanical stress, or of generating mechanical stress when subjected to an electric field.[6]

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IV. OBJECTIVESOFTHEPROJECT

The objectives of piezoelectric roads encompass various aspects, including energy generation, sustainability, technological innovation, and environmental impact.
Here is a comprehensive list of objectives associated with piezoelectric roads:

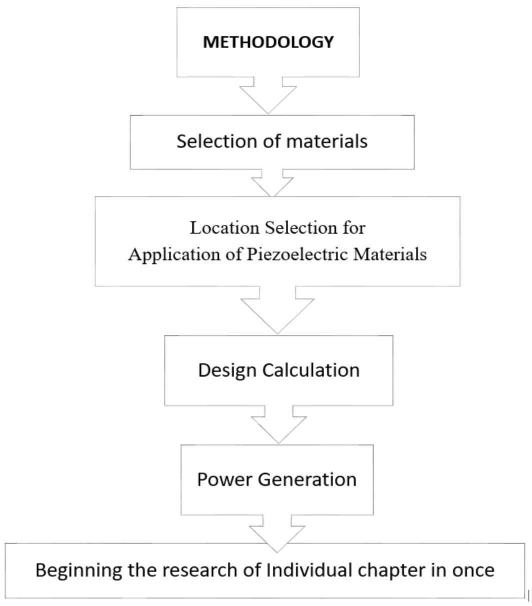
1. **Clean Energy Generation:** Harvest mechanical energy from the movement of vehicles to generate clean and renewable electricity.
2. **Sustainable Infrastructure:** Contribute to the development of sustainable and environmentally friendly infrastructure.
3. **Smart Cities Integration:** Align with the concept of smart cities by integrating technology into urban infrastructure for enhanced efficiency and sustainability.
4. **Integration with IoT Devices:** Power sensors, smart lighting systems, and other IoT devices to make cities more intelligent and responsive.
5. **Optimization of Transportation Energy:** Optimize the use of energy resources associated with transportation by capturing energy that would otherwise be wasted.

V. PROBLEM STATEMENT

The implementation of piezoelectric roads faces several challenges and problems. Here is a comprehensive list of issues associated with piezoelectric roads:

1. **Material Selection:** Identifying durable and cost-efficient materials capable of converting mechanical strain into electrical energy while withstanding traffic loads and environmental conditions.
2. **Energy Conversion Efficiency:** Improving the efficiency of the piezoelectric material to maximize the conversion of mechanical energy from moving vehicles into electrical power.
3. **Integration with Infrastructure:** Ensuring seamless integration of piezoelectric elements into existing road infrastructure without compromising road safety, durability, or maintenance requirements.
4. **Scalability:** Designing scalable solutions that can be implemented on a larger scale, considering different road types, traffic conditions, and geographical locations.
5. **Environmental Impact:** Assessing the environmental impact of the manufacturing process, deployment, and end-of-life disposal of piezoelectric road systems, aiming for sustainability and minimal ecological footprint.

VI. METHODOLOGY



Our project aimed at generation of electricity from queen's necklace road for which we will first identify the area covered by the road and the factor which should be considered during the planning of the project next we will collect the data regarding materials and selection of appropriate materials. Collection of the data related to the area, population, traffic which majorly contribute toward the volume over the location. Considering various important factors of planning we will calculate the quantity of piezoelectric sensors. Estimating overall budget by planning on paper and then finalize it by experts.

6.1. Selection of Materials

1. Fine Gravel and Sand:

Gravel, alongside the sand, is employed for the manufacture of concrete, and also for mixing with asphalt as a part of the construction. The bottom layer essentially comprises an unbound mixture of coarse and fine crushed stone, as well as crushed sand, to achieve the desired load-bearing capacity and absorb traffic loads so that the underlying subgrade is not deformed.

2. Asphalt:

Asphalt is most often used for road surfacing, which can be achieved in a number of ways. Repetitive light oil "dust layer" treatments may be used to create a hard surface, or granular aggregate can be applied to an asphalt coat, or earth materials from the road surface can be combined with the asphalt.

3. Piezoelectric Generators:

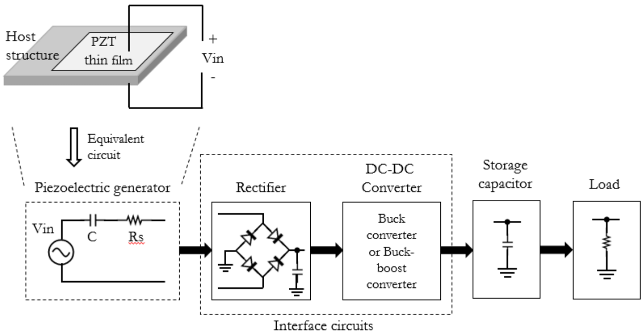
A piezoelectric generator is a power generation device that works on the principle of piezoelectricity and it holds the ability to convert mechanical energy. For example, vibrations in the piezoelectric materials are converted to electric energy. For this kind of energy harvesting procedure, any of the piezoelectric materials from four classifications can be considered. But the foremost material used for energy conversion in generators is ceramics and it can also be grouped up with few monocrystals, composites, and polymers.

4. Bitumen Sheet:

Bitumen, also known as asphalt, is a sticky, black and highly viscous liquid or semi-solid form of petroleum. Thanks to its waterproofing qualities, it is widely used in construction. Bituminous membranes are perfect for waterproofing roofs, basements, below-ground structures, bridges and other structures.

5. Harvesting Mechanism:

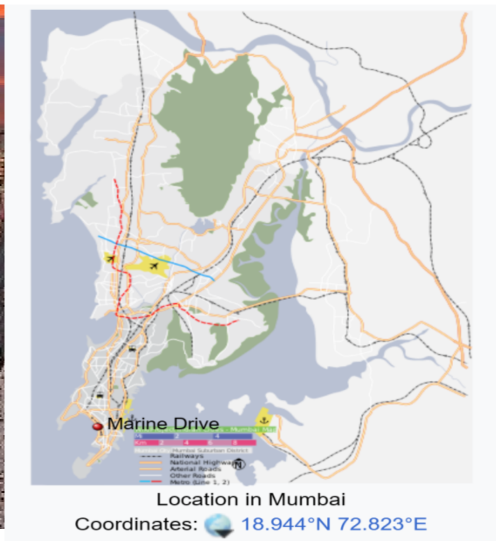
The mechanical energy of the vehicles is harvested and converted to electrical energy by generators. Electrical energy is transferred and stored via a harvesting module. Then, it is charged into the battery on one side of the road..[7]



6.2. Area Selection for Application of Piezoelectric Materials:

Marine Drive is a 3 kilometre-long Promenade along the Netaji Subhash Chandra Bose Road in Mumbai, India. The road and promenade were constructed by Pallonji Mistry. It is a banana-shaped, six-lane concrete road along the coast of a natural bay. At the northern end of Marine Drive is Girgaon Chowpatty and the adjacent road along links Nariman Point at southern tip to Babulnath and Malabar Hill at northern tip. Marine Drive is situated on reclaimed land facing west-south-west. Marine Drive is also known as the *Queen's Necklace* because, when viewed at night from an elevated point anywhere along the drive, the street lights resemble a string of pearls in a necklace.

The generating capacity of piezoelectric devices can be crudely over-approximated by assuming that the vibrations in the road are caused by traffic alone, and that each "vibration event" from one vehicle is independent of another (i.e. the vibrations are sufficiently dampened before the next vehicle passes). Under these assumptions, the total energy harvested by piezoelectric devices along a one-kilometer stretch is at most the number of cars that pass multiplied by the vibrational energy that one car transfers to the road. This vibrational energy can be over-approximated by the energy that each car consumes and puts to mechanical work across this stretch. In other words, the energy a car loses to vibrations in asphalt must be less than the energy a car puts to mechanical work over the one-kilometer stretch.



6.3. Design Calculation & Cost Estimation for 1km road[8]:

- Size of road: length = 1km = 1000 m, width = 2 m
- Area of road = length*width = 1000*2= 2000 sq.m
- Size of 1 sensor: 1 sq.ft = 0.0929 sq.m
- Gap between two sensors: 1.5 (from each side) = 1.5*2 = 3 m
- Area of road on which sensors been installed: 2000/3 = 666.67 sq.m= 667 sq.m
- No. Of Sensors required for 1 km road = Area of road/size of one sensor = (667/0.0929) = 7179.76 = 7180 Nos.
- Cost of 1 sensor = 1000 Rs (approx)
- Cost of 7180 sensors = 7180 × 1000 = 7180000 Rs = 70 lakhs (approx)

6.4. Power Generation:

- Case study: Queen's Necklace Road Project
- Overall Budget of the Project: 117crore
- 6 lane road of 3 km stretch is laid.
- No. Of Sensors required for 1 km road = 3 × 6 × 7180 = 129240 Nos.
- Cost of 123240 sensors = 129240 × 1000 = 129240000 Rs = 13 crores
- Overall Budget of the Piezoelectric Road = 130 crore
- If Piezoelectric Road constructed, the budget of project = 1.2 times overall budget = 1.2 × 117 crore
- Energy generated from 1 km single lane road = 44000 kw per year
- Energy generated from 3 km 6 lane road = 3 × 6 × 44000 kw = 792000 kw energy generated
- Government of India charges Rs. 5 on average per 1 kwh,
- Hence, cost of 792000 kwh = 7 × 792000
  = Rs.5544000 (55 lakhs)
- The amount which is invested on this road will get returned in only 24 years.
- This piezoelectric road has an average life of 50 years
- Hence, income generated in the next 26 years would be a profit.
- No. of Street lights at Queen's Necklace Road = 650
- Energy required for one Street light = 200 Watt
- For 650 Street Lights = 130000 Watt

Using the average EV's energy consumption, a home EV charger would use around 11.81 kWh per day to charge the car to replenish the range driven. This translates to about 353.3 kWh per month and 4,310.65 kWh per year.appropriate style is still applied to each section, reapplying styles if necessary.

VII. CONCLUSION

These project is mainly focused on generating enough electricity by making use of piezoelectric materials for the electrification of street lights on highways.

It can also be used to power the sign boards.

The busy roads and airports can also be the specified areas for the Installation for the piezoelectric material for harnessing the Electrical energy for various uses.

Energy harvesting from the embedded piezoelectric generator is an attractive technology that can harness the excess energy wasted on the highway caused by moving vehicles.

The energy output of the embedded piezoelectric generator was 792000 kW per year, which is quite enough to light 6 high-pressure sodium (HPS) street lights of 200 W.

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