Feature Presentation

NJDOT Sustainability Initiatives

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Bureau of Research

SUSTAINABLE RESEARCH PROJECTS- NJDOT BUREAU OF RESEARCH

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OUTLINE:

- Materials
  - Porous concrete
  - Rubber concrete
- Energy Harvesting

IMPLEMENTATION OF PERVIOUS CONCRETE IN SIDEWALKS IN NEW JERSEY

- **What is pervious (porous) concrete?**
- **Phase I : Evaluation of various mixes for mechanical properties, workability, and durability**
- **Phase II : Implementation in sidewalks**

WHAT IS PERVIOUS (POROUS) CONCRETE?

‘PERVIOUS CONCRETE IS A PERMEABLE MATERIAL, TYPICALLY MADE FROM CEMENT, AGGREGATES, WATER AND ADMIXTURES, OFTEN BUILT WITH AN UNDERLYING STONE RESERVOIR THAT TEMPORARILY STORES SURFACE RUNOFF BEFORE IT INFILTRATES INTO THE SUBSOIL

THERE ARE SEVERAL BENEFITS FOR USING PERVIOUS CONCRETE IN PAVEMENTS. ONE OF THE MOST IMPORTANT BENEFITS IS ITS EFFECTIVENESS IN ELIMINATING SURFACE RUNOFF FROM STORM WATER- THUS REDUCING POTENTIAL FOR FLOODING, PUDDLING, EROSION AND HAZARDS’

PHASE I

EVALUATION OF VARIOUS MIXES FOR MECHANICAL PROPERTIES, WORKABILITY, AND DURABILITY

Recommended Mix Proportions for Porous Concrete (per cubic yard)

550 – 650 lbs. of cement type I/II
2500-2800 lbs. of 3/8 in aggregates
Fine aggregates (maximum 7% of the total weight of aggregates)
Fly ash (maximum 15% weight of cement)
Slag (maximum 20% weight of cement)
0.27- 0.33 water/binder ratio
High Range Water Reducer (1.8 to 2.0 lbs)
Viscosity modifier (1.8 to 2.0 lbs)
Hydration stabilizer (1.8 to 2.0 lbs.)
Air entrainer (0.78 lb.)

Recommended Properties for Porous Concrete

15% to 25% air void content
105 to 125 lb/ft^3 unit weight
2000 to 3000 psi strength
Drainage rate 3-5 gal/min/ft^2 (equivalent of 100- 300 in/hr)

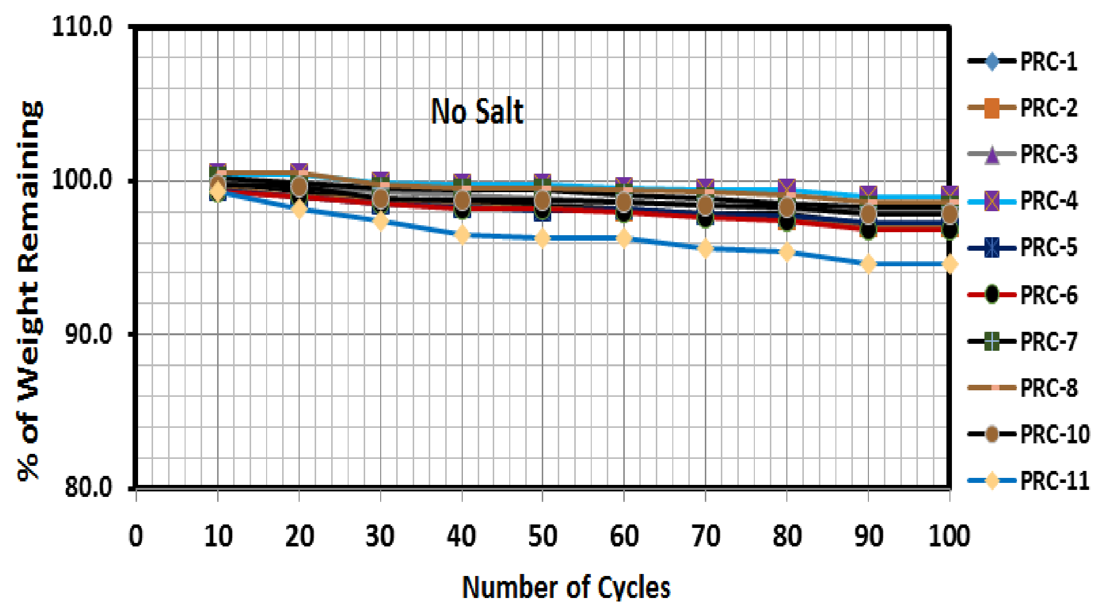
(NRMCA, NJDEP, NJDOT, PCA, NJDOT,TDOT)

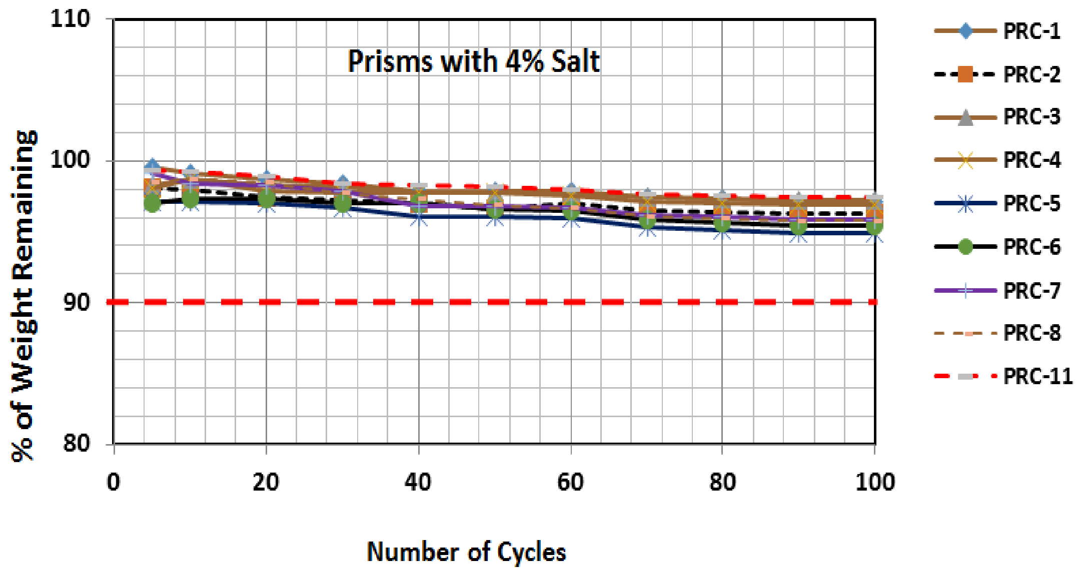
EXPERIMENTAL PROGRAM

Mix	Cement	3/8 Agg	1/4 Agg	Sand	Fly Ash	Slag	Water	W/CM Ratio	MRWR (SP)	HS	VMA	AE
PRC-1	635	2430	---	224	---	---	209	0.33	---	---	---	---
PRC-2	864	2430	---	---	---	---	236	0.27	1.9	1.9	---	0.8
PRC-3	600	2835	---	---	---	---	162	0.27	1.9	1.9	---	0.8
PRC-4	620	2700	---	---	---	---	168	0.27	1.9	1.9	---	0.8
PRC-5	620	2700	---	---	---	---	168	0.27	1.9	1.9	2	0.8
PRC-6	620	1380	1380	---	---	---	168	0.27	1.9	1.9	---	0.8
PRC-7	525	2500	---	---	95	---	168	0.27	1.9	1.9	---	0.8
PRC-8	465	2500	---	---	---	155	168	0.27	1.9	1.9	---	0.8
PRC-9	500		2700	---	---	---	165	0.33	1.9	1.9	---	0.8
PRC-10 (gravel)	600	2700	---	---	---	---	180	0.3	1.9	1.9	---	0.8
PRC-11 (gravel)	600		2700	---	---	---	180	0.3	1.9	1.9	---	0.8

POROUS CONCRETE- LAB TESTING

Freeze-thaw tests



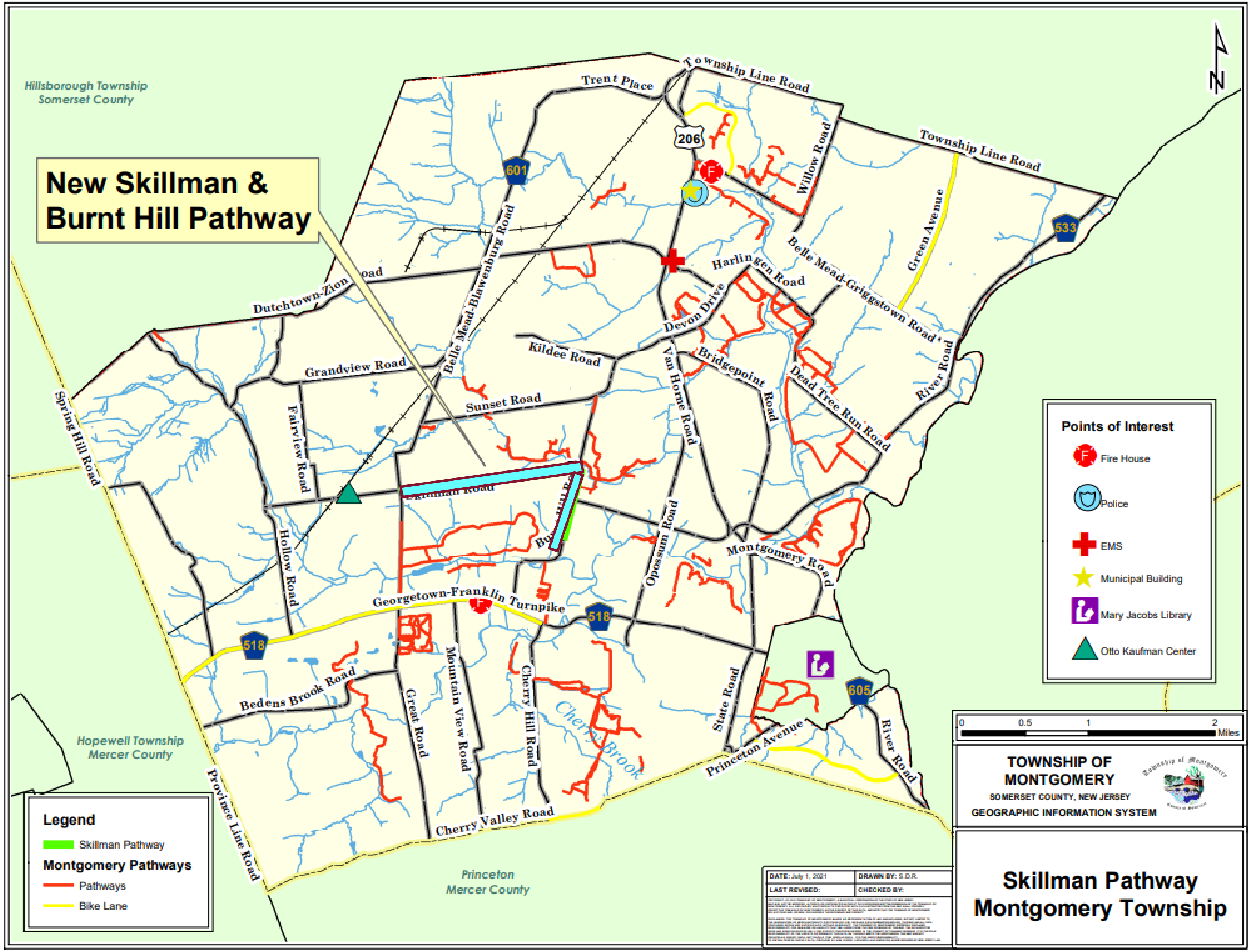


POROUS CONCRETE-FIELD TESTING

PHASE II

IMPLEMENTATION

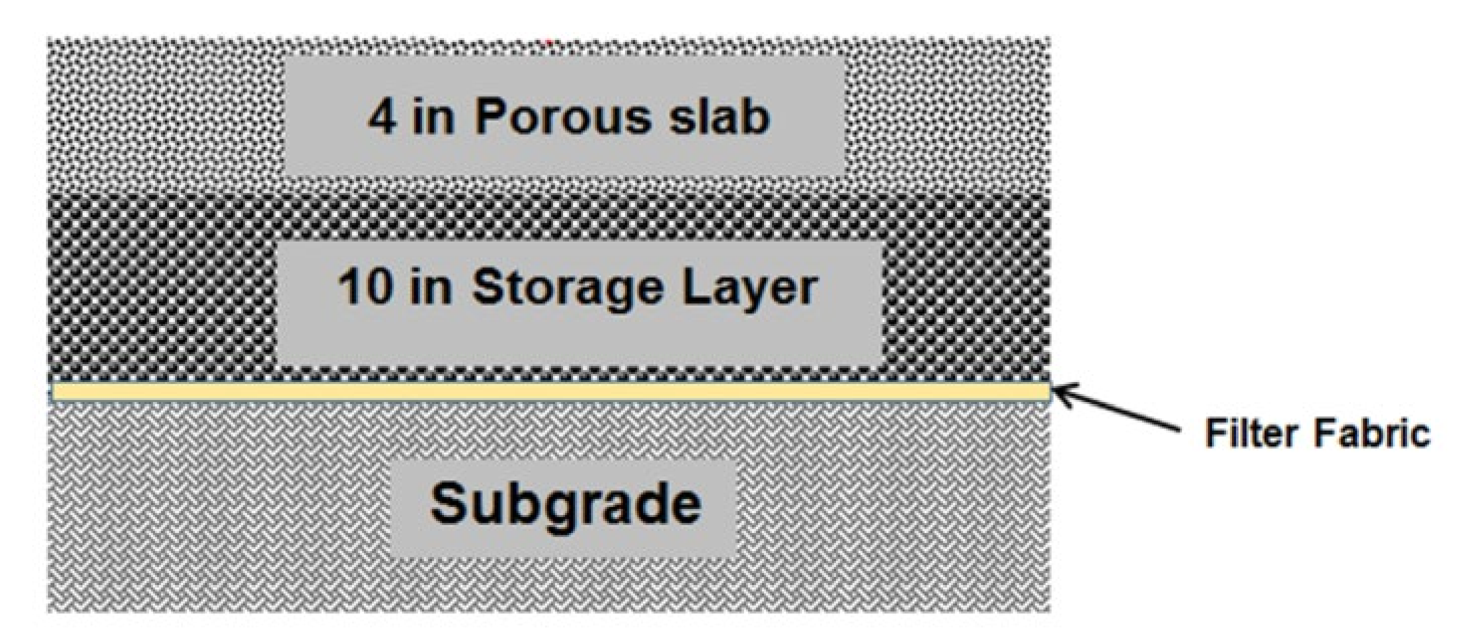
SIDEWALK LOCATION- MONTGOMERY TOWNSHIP



STRUCTURAL AND HYDROLOGICAL DESIGN

THE NRCS AND CURVE NUMBER (CN) METHOD WAS USED FOR DESIGN OF THE STORAGE LAYER

4 IN MINIMUM THICKNESS FOR SIDEWALKS
10 IN OPEN-GRADE STONE STORAGE LAYER
STORAGE LAYER (NO. 2 AND NO. 57 COARSE AGG , ASTM C33)
NON-WOVEN GEOTEXTILE FILTER FABRIC
MINIMALLY COMPACTED SUBGRADE (92% +/- 2%)
1/2 IN EXPANSION JOINT WITH JOINT FILLER EVERY 20 FT



Preparation of the sidewalk

Preparation of the sidewalk

Placement of expansion joint filler

CONCRETE PLACEMENT

Concrete Placement and finishing

Finished section

FINISHED SURFACE

COLLECTION OF FIELD SAMPLES (BEAMS AND CYLINDERS)

After Hurricane Ida

Maintenance

- **Visual Inspection**
- **Infiltration Tests**
- **Air Blowers to remove debris**
- **Vacuum Cleaning for more effective cleaning**
- **Pressure Washing to remove clogging**

Visual Inspection of Existing sidewalk

Well maintained

Visual Inspection of Existing sidewalk

Somewhat Maintained

Visual Inspection of Existing sidewalk

Poorly Maintained
Moderate to Severe Raveling and Clogging

Infiltration Test (ASTM 1701)

Air Blowers

Vacuuming

Pressure washing is needed when there is clogging

Water pressure of 2000 psi is sufficient to removed minor to moderate clogging

Pressure washing is needed when there is clogging

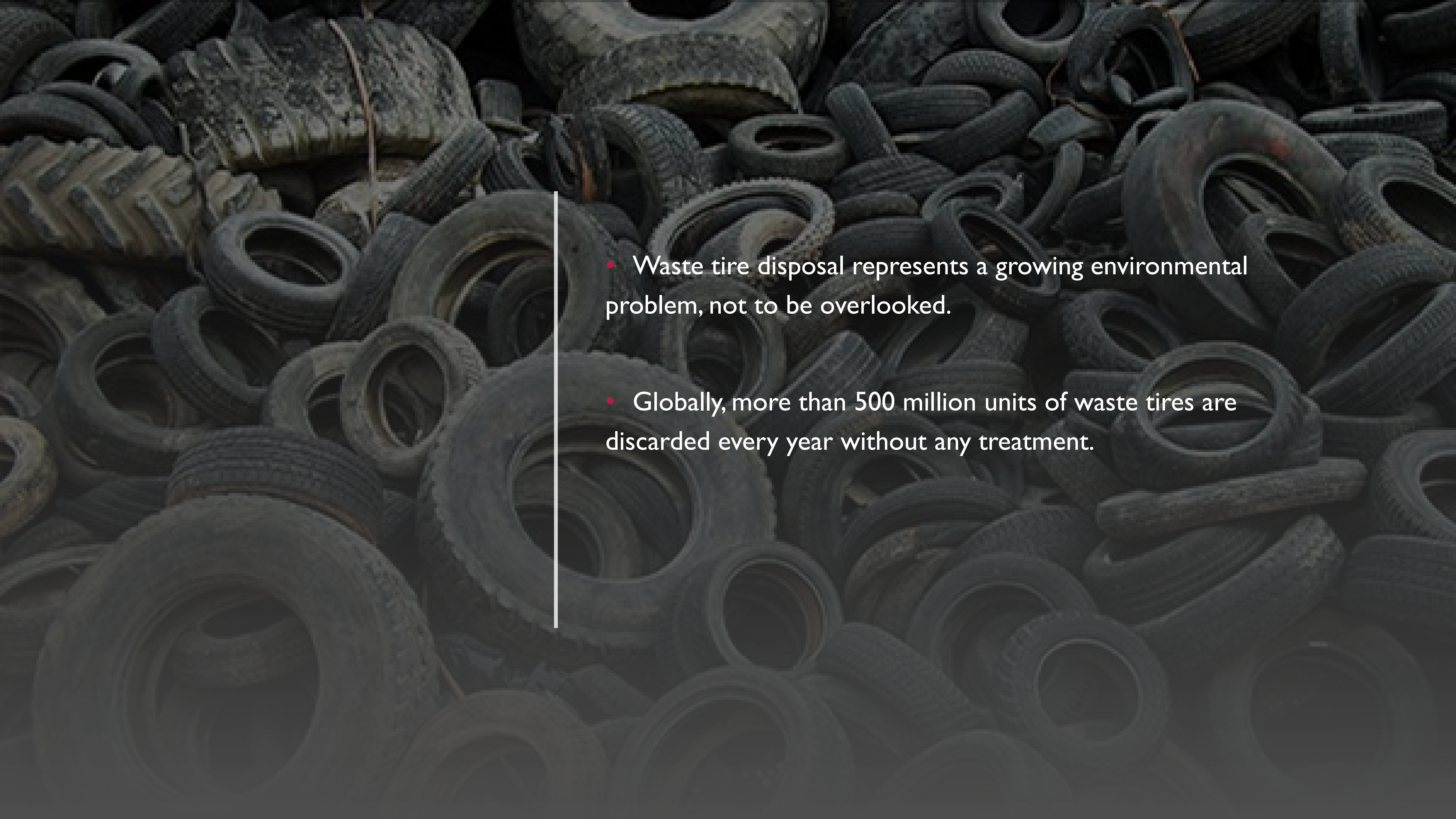
Water pressure of 3000 psi to 3500 psi is sufficient to remove moderate to severe clogging

Pressure washing is needed when there is clogging

Water pressure of 3000 psi to 3500 psi is sufficient to remove moderate to severe clogging

Sidewalk after pressure washing with 3000 psi water pressure

RUBBER CONCRETE



- Waste tire disposal represents a growing environmental problem, not to be overlooked.
- Globally, more than 500 million units of waste tires are discarded every year without any treatment.

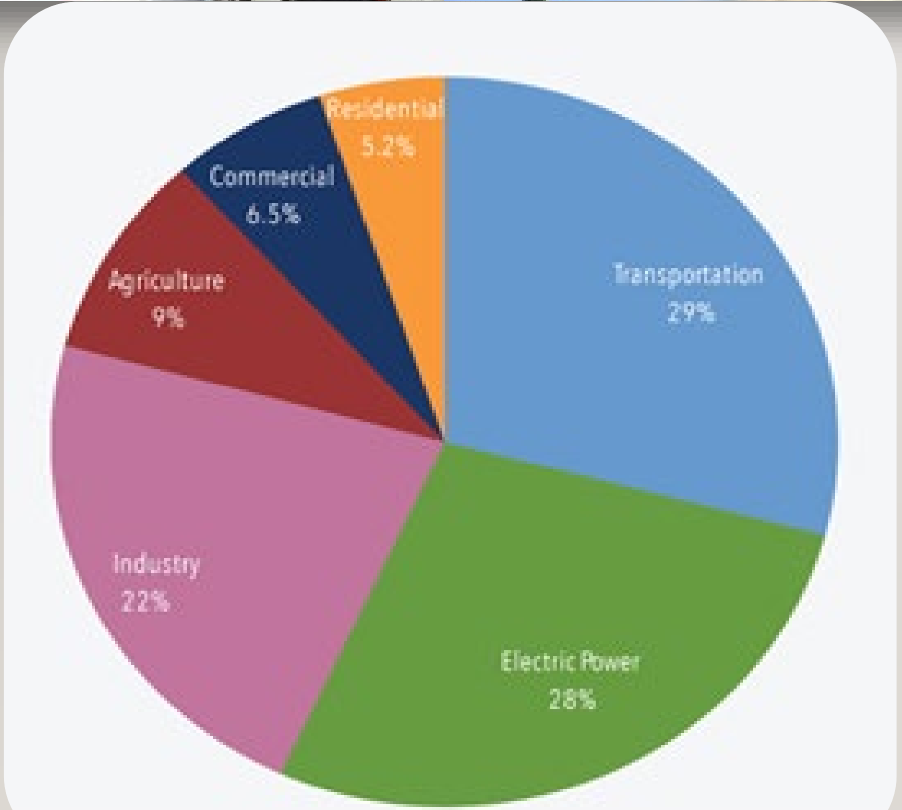
- Their increasing number has raised concerns worldwide due to the threat they pose directly and indirectly to human health and the environment. For this reason, recycling of waste tires has been implemented in many countries.

The possibility of recycling scrap tires as aggregates in concrete/asphalt gained acceptance worldwide in the engineering sector, and positive results have already been achieved, preserving natural resources, and helping to maintain ecological balance. NJDOT Bureau of Research is currently looking into this material for possible applicability on roadway applications.

Sidewalks

Asphalt road

ENERGY HARVESTING FROM ROADWAY AND BRIDGE



GHG generation by sector (2017)

CHALLENGE AND MOTIVATION

Growth of traffic and deterioration of infrastructure

- Transportation agencies are under a great challenge to monitor roadway network condition and traffic operations

More than 80% of energy production from fossil fuels (IEA)

- Release of large amount of CO_2 and cause climate change issues

Energy harvesting can provide renewable energy solutions for different transportation applications

RESEARCH MOTIVATION

- Traditional solar farms (ground-mounted solar panels) require a large amount of land, especially when targeting high energy production.
- Photovoltaic noise barriers (PVNBs) use photovoltaic technology to produce renewable energy and simultaneously abate the noise generated from traffic.
- Few studies have been conducted to evaluate the design of PVNBs and the practical issues and challenges for real implementation

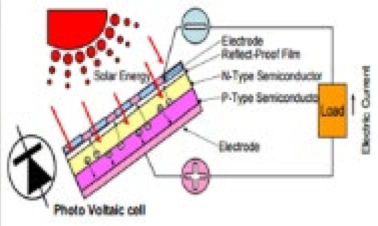
ENERGY HARVESTING AND BENEFITS

- Harvesting waste energy from transportation infrastructure and use it for sustainable and smart transportation.

- **Large-scale application:**
- Provide clean and renewable energy solutions for different uses, especially at remote off-grid regions.
- Reduce environmental impact of generating the amount of harvested energy.
- **Micro-scale application:**
- Provide continuous power supply for lighting, self-powered sensor device, and wireless data transfer.
- Serve as smart sensor at the same me to monitor traffic data and infrastructure condition.

PHOTOVOLTAIC ENERGY HARVESTING

- Photovoltaic materials generate electricity with application of light.
- Polycrystalline panels made of silicon crystals are the most common solar panel.
- Wide applications on different types of roadway assets.

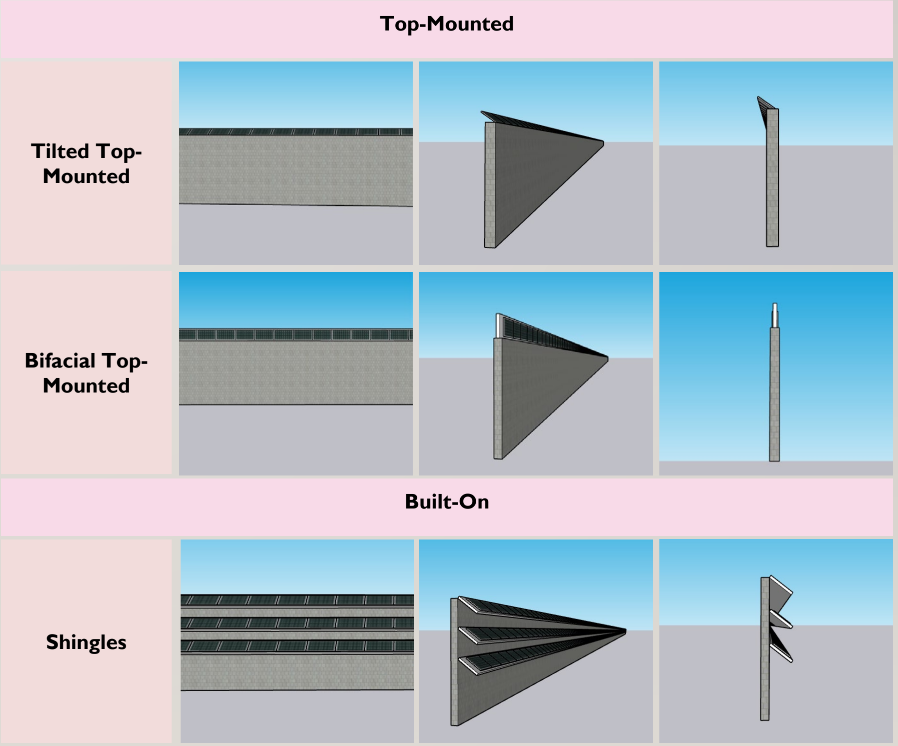






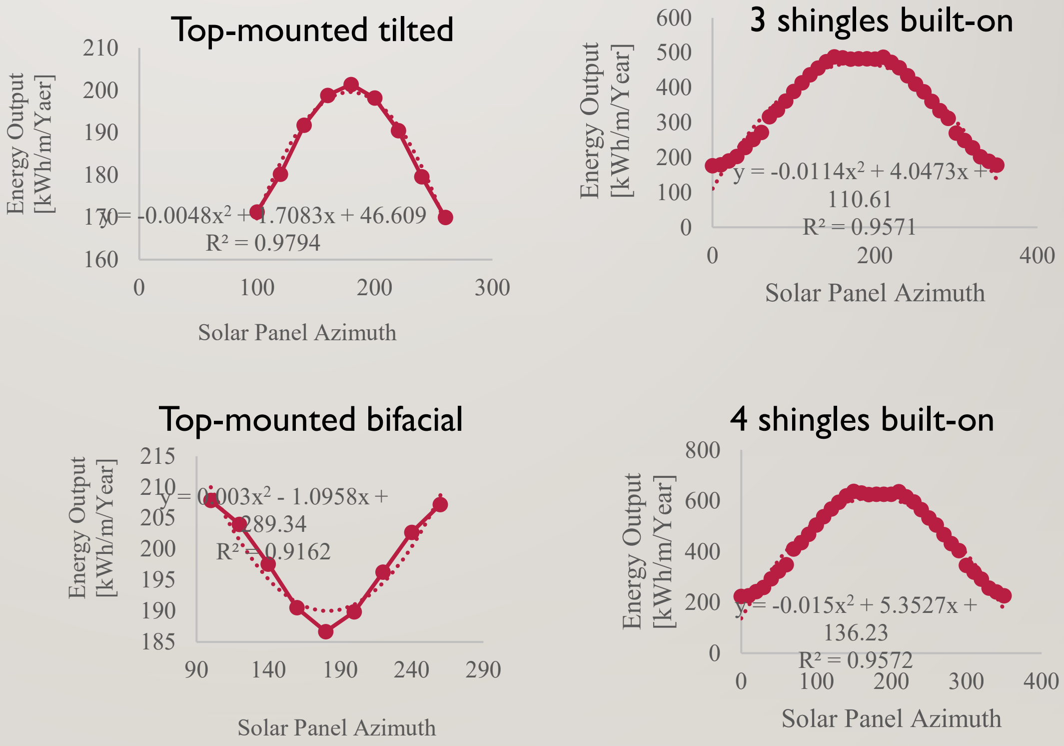

RESEARCH OBJECTIVE AND SCOPE

- Conduct comprehensive study of PVNBs for evaluation of design configurations and discussion of implementation issues.
  - Three retrofitting designs of PVNB were compared and evaluated through site-specific analysis.
  - Energy simulation was conducted to develop simplified models for state-level estimation in NJ.
  - Business models and implementation challenges.



EFFECT OF PVNB DESIGNS AND ORIENTATIONS

- Analysis tool: Sketchup with Skelion plug-in that uses PVWatts (NREL) for estimation of solar energy production.
- Optimum configuration of solar panels were considered.



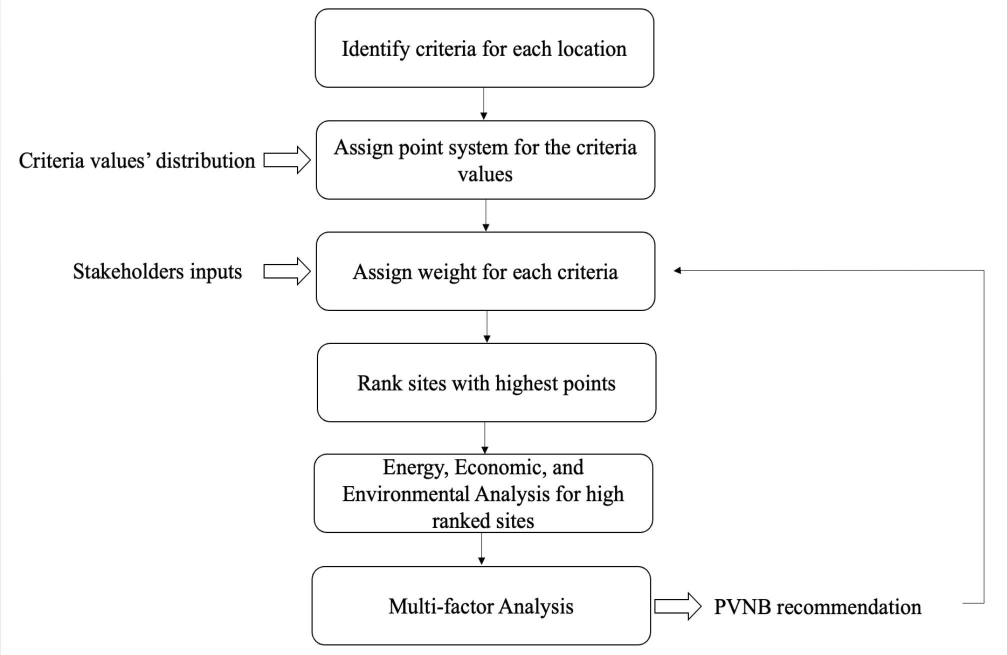
STATE-LEVEL ENERGY ESTIMATION

- Currently, there are 72 noise barriers in New Jersey totaled 10,268,832 square feet along 106.3 miles. The average height of noise barrier is 17 ft.
- The beginning and ending latitude and longitude of each barrier segment were used to find average orientation and length of each segment.

PVNB Configuration	Energy Output (MWh/Year)
Top-mounted Tilted	27,196
Top-Mounted Bifacial	21,246
Built-on 3-shingles	48,934
Built-on 4-shingles	56,164

SITE SELECTION OF PVNB

- **Economic**
  - Solar Irradiation
  - Barrier direction
  - Distance to power grid
  - Accessibility for maintenance
- **Environmental**
  - Solar Irradiance
  - Barrier direction
  - Region electricity source
- **Social**
  - Highway traffic
  - Electricity rate
  - Electricity availability
  - Distance from barrier to highway shoulder

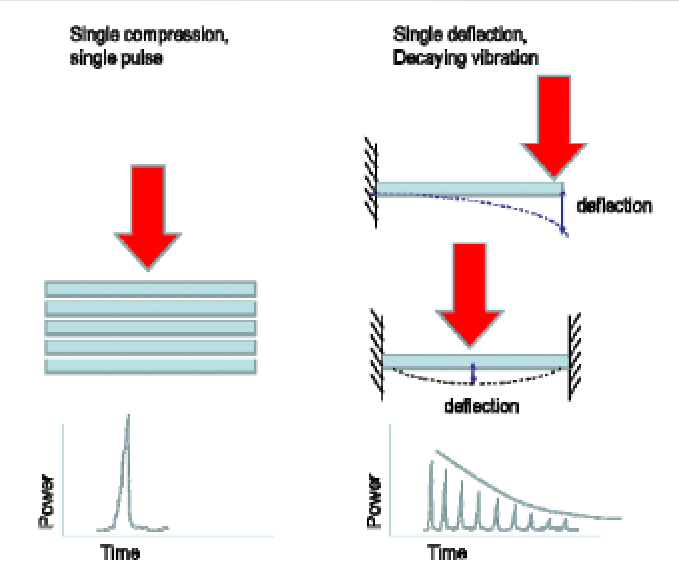


CONCLUSIONS

- In the project level, the design configuration with shingles has the highest energy output; while the energy outputs of top-mounted configurations vary depending on barrier orientation.
- The simplified regression models provide a quick way to estimate total energy output for each design configuration considering different orientations of noise barriers.
- The proposed decision-making framework for site selection includes factors that impact these three categories to increase monetary gains, decrease environmental impacts, or increase public welfare.

PIEZOELECTRIC ENERGY HARVESTING

- Piezoelectric materials generate electric charges when subjected to mechanical stresses or change geometric dimensions when an electric field is applied.
- Common piezo materials include lead zirconate titanate (PZT), Polyvinylidene fluoride (PVDF), and piezoelectric composite.
- The energy harvesting performance of piezoelectric transducer is affected by material, geometry design of transducer, and external loading.



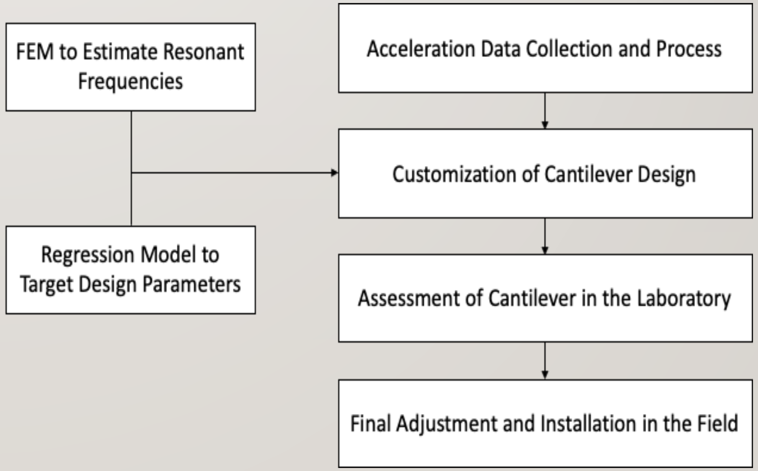
Energy harvesting + Sensing

RESEARCH MOTIVATION

- For piezoelectric energy harvesting on pavements, most relevant designs are compression-based and require structural integration with the existing pavement structures.
- Vibration-based energy harvesters have less impact on host structure without embedment needed and require less effort in installation.
- The power outputs from vibration-based energy harvesters are strongly affected by the host structural vibration, which may be uncertain with multiple vibration frequencies.

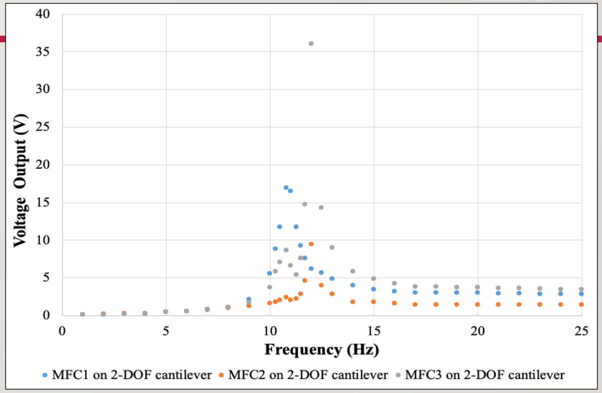
RESEARCH OBJECTIVE AND SCOPE

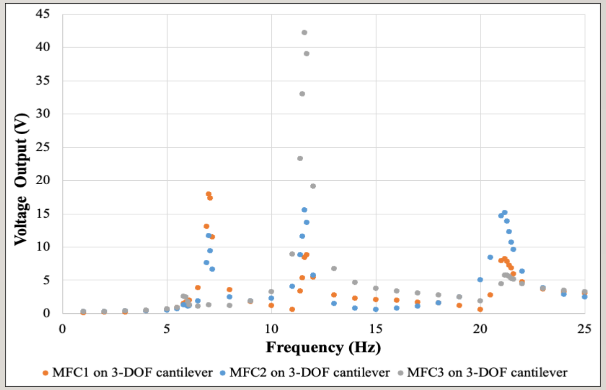
- Develop novel piezoelectric cantilevers to generate power from bridge structure vibration.
- Propose an optimization approach for customizing the design to maximize power outputs due to bridge vibrations.
- Laboratory testing, numerical simulation, and full-scale test.



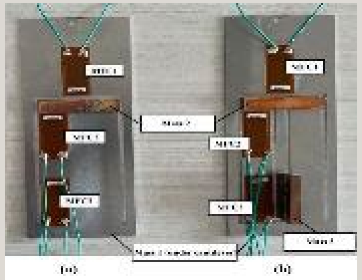
LABORATORY TESTING

- Cantilever designs with multiple degree of freedom (DOF)
- The voltage outputs under different vibration frequencies were collected and the resonant frequencies and the corresponding voltage outputs were determined



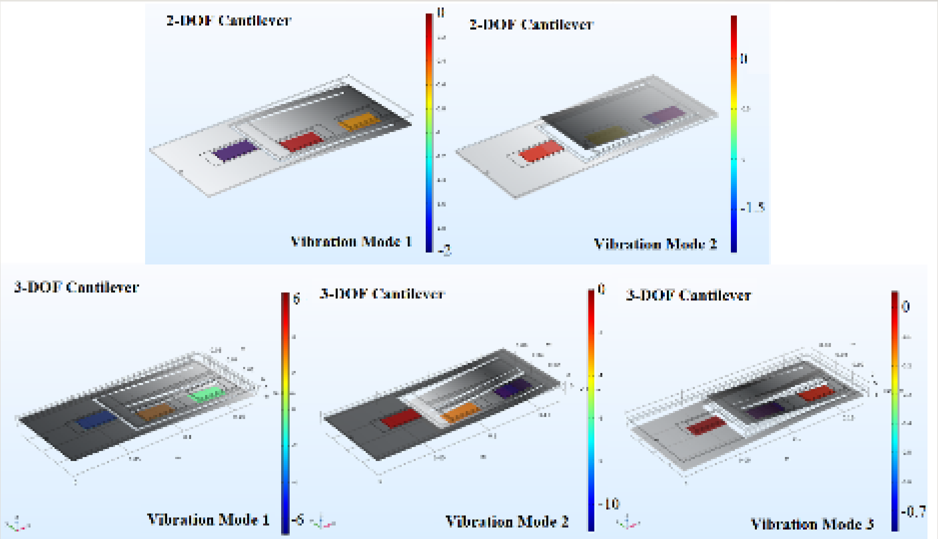


2-DOF and 3-DOF Cantilevers



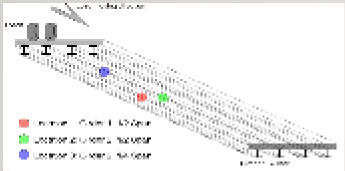
NUMERICAL MODELING

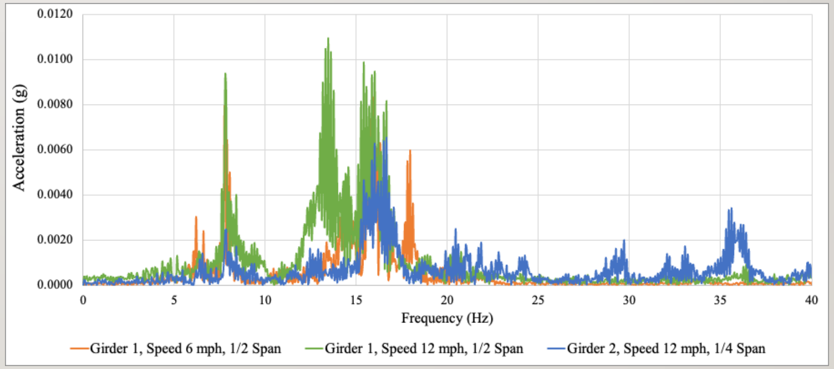
- Multi-physics models are developed to predict the resonant frequency under frequency sweep simulation and verified with laboratory tests.
- FEM cases were run to develop the regression models between resonant frequencies and mass combinations.

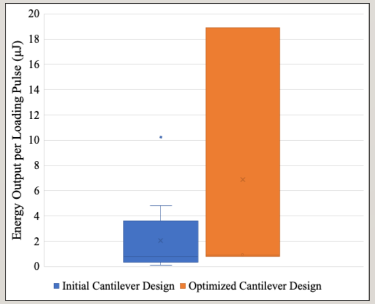


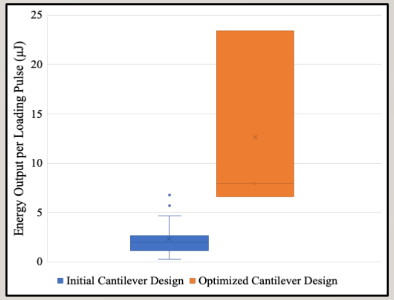
Voltage outputs from MFCs on 2-DOF and 3-DOF cantilevers under different vibration modes

FULL-SCALE BRIDGE TEST









2-DOF and 3-DOF Cantilevers at ½ span of girder 1

Thank You