ISAP

Technical Committee on Asphalt Pavements and Environment

Working Group 7
Energy Harvesting

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Scope

- Investigating novel methods to harvest solar energy from asphalt pavements utilizing the-state-of-the-art and/or innovative approaches to reduce heat island effects and global warming etc.

Strategic Plan

- Review literatures and practices to investigate novel methods to harvest solar energy
- Generate different approaches to capture solar energy
- Formulate conceptual design of systems to generate electricity
- Prepare the feasibility study report for the detailed and comprehensive study

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Asphalt Pavements

- Hot Mix Asphalt (HMA)
  Warm Mix Asphalt (WMA)
  Cold Mix Asphalt (CMA)
- Heat island effect
- Climate change
- Other averse consequences

All day long pavements receive solar energy from the sun rays, storing much of them as heat that is left to dissipate by nightfall.

The concept of harvesting solar energy from asphalt pavement is enticing because it offers a way to collect solar energy by utilizing an extensive infrastructure that already exists.

Thus, there is a need to investigate novel methods for solar energy harvesting and conversion with potential economic efficiency substantially beyond that of current technology.

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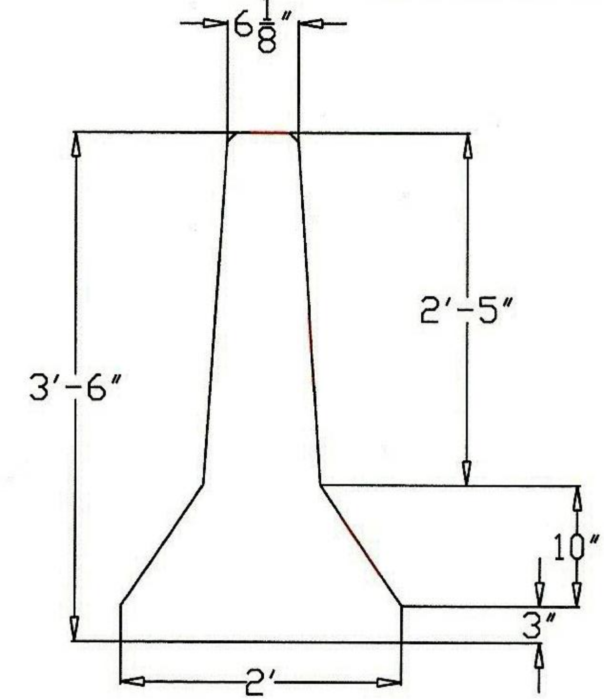
Methods for Harvesting

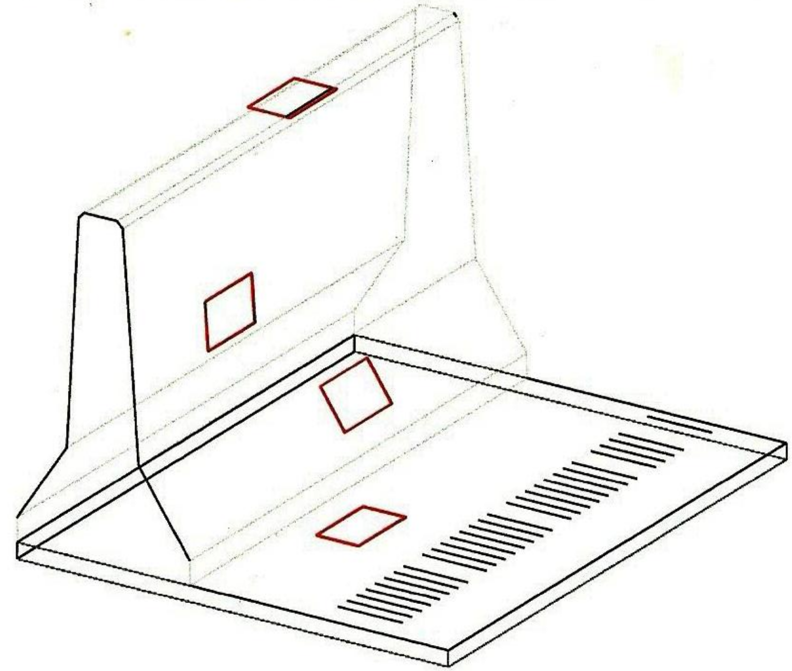
- Using flexible photovoltaic cells to harvest solar energy in unused areas of pavement
- Creating a solar system that uses drop in solar panels as the roadway
- Embedding highly conductive pipes within asphalt pavement for heat extraction
- Using the Seebeck effect with organic semiconductors embedded in asphalt pavement to generate electricity

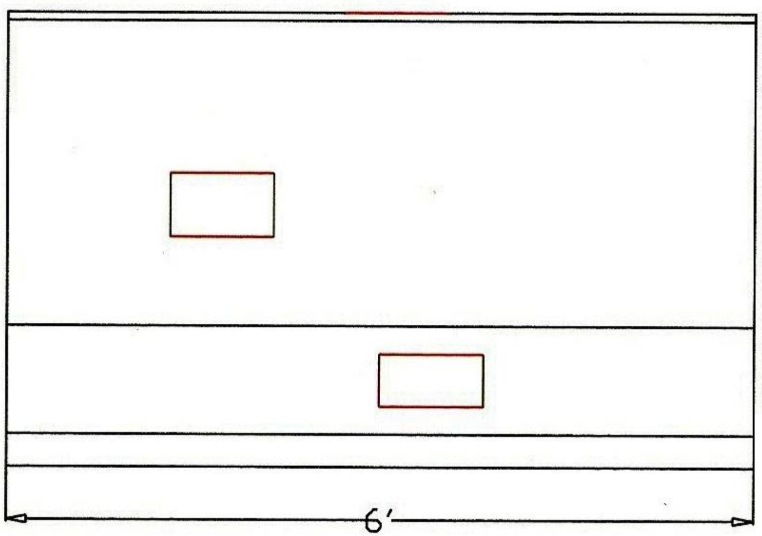
(1) Photovoltaic Method

Photovoltaic Method

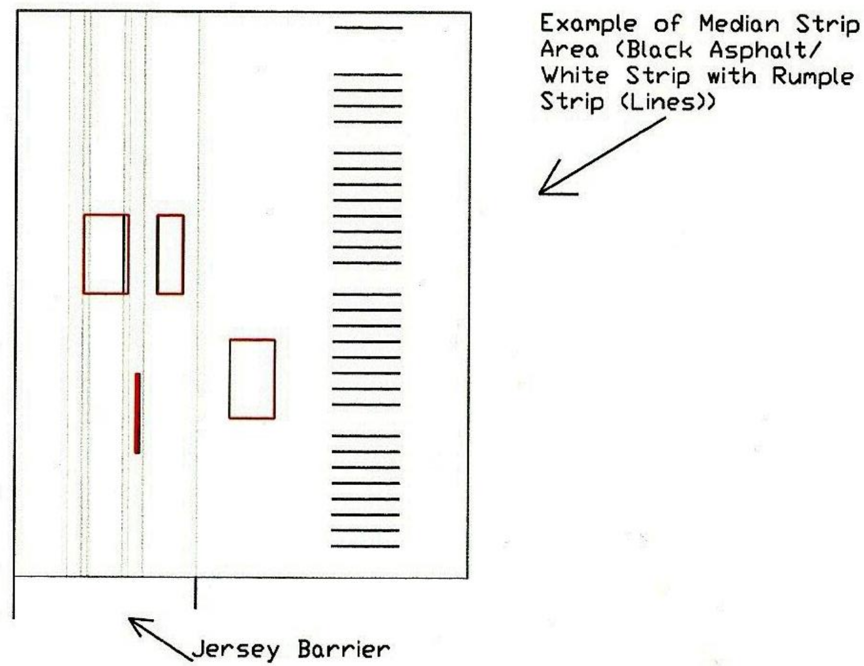
- A simple and convenient approach to utilize the current photovoltaic technologies
  - Concentrated mostly on the flexible photovoltaic cell for their ease of placement
- These cells can be installed where no or little traffic occurs, e.g., between NJ barrier and the rumble strip in the median
  - A potential product is a Photovoltaic laminate with a potted terminal housing assembly with output cables and quick terminals for ease of application to existing electrical connections







Panel (Red) Dimesions: 10"x5.9"x.02"



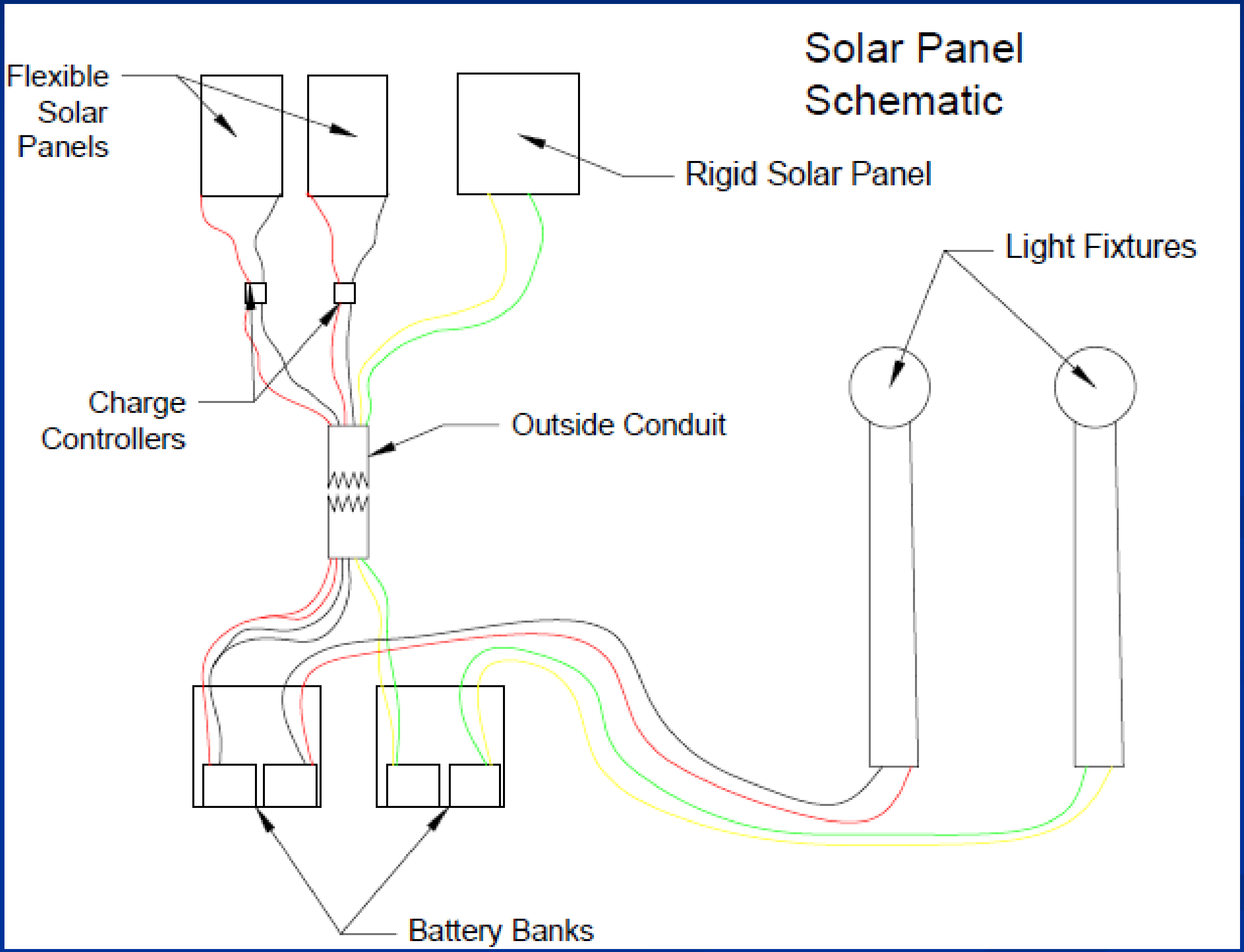
Photovoltaic Method

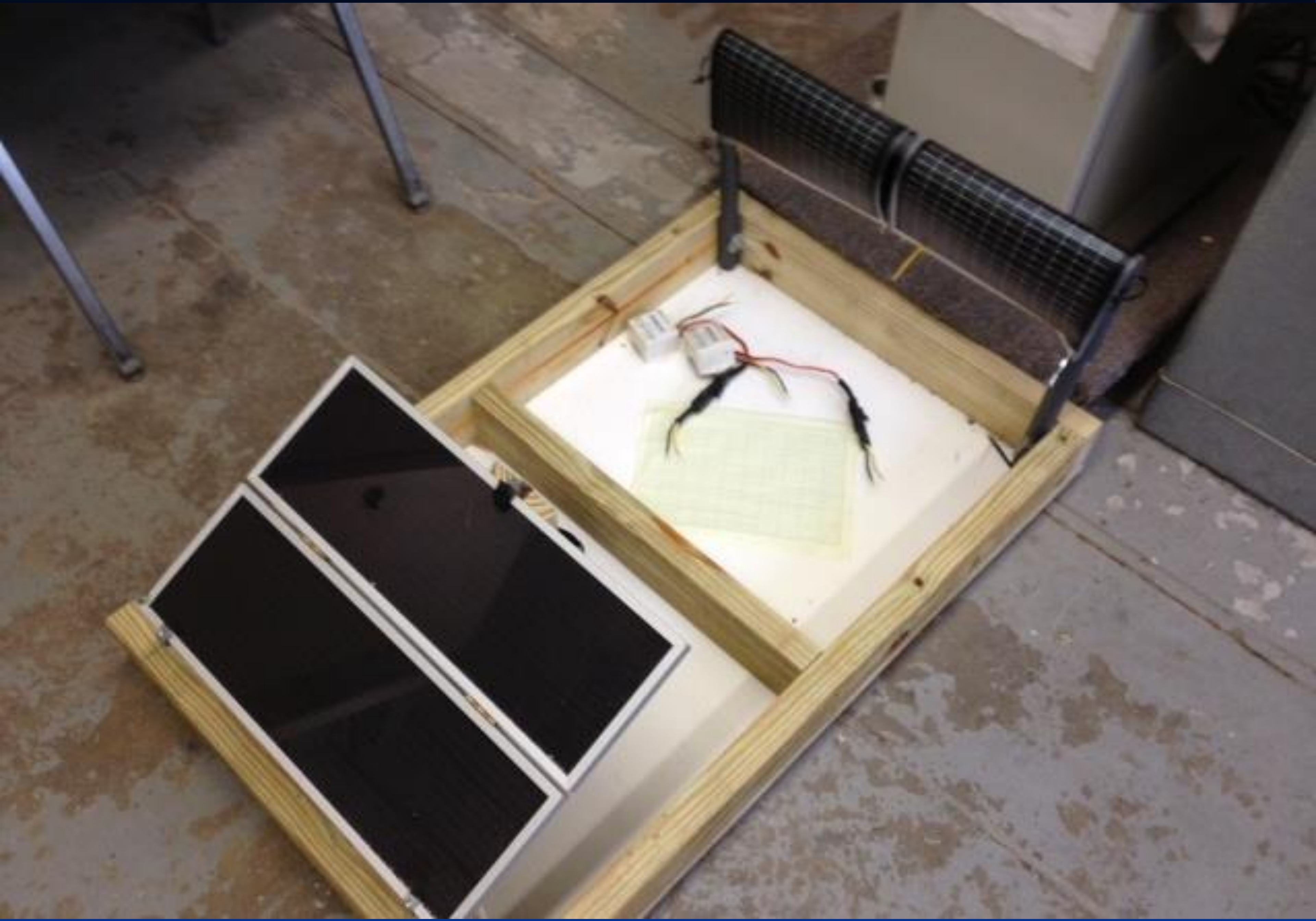
- It has shown that simple flexible panels can be used effectively to simulate real world situations at URI

Photovoltaic Method

- Testing has begun with a main focus on the efficiency differences between flexible and rigid panels
  - It is comprised of a fixed structure on the roof of Bliss Hall, that hold both types of panels
  - The panels are connected to separate battery banks so that power generated by each panel can be compared
  - The battery banks are connected to 2 exterior lamp lights at the entrance of Bliss Hall so that a visual comparison can be shown to students

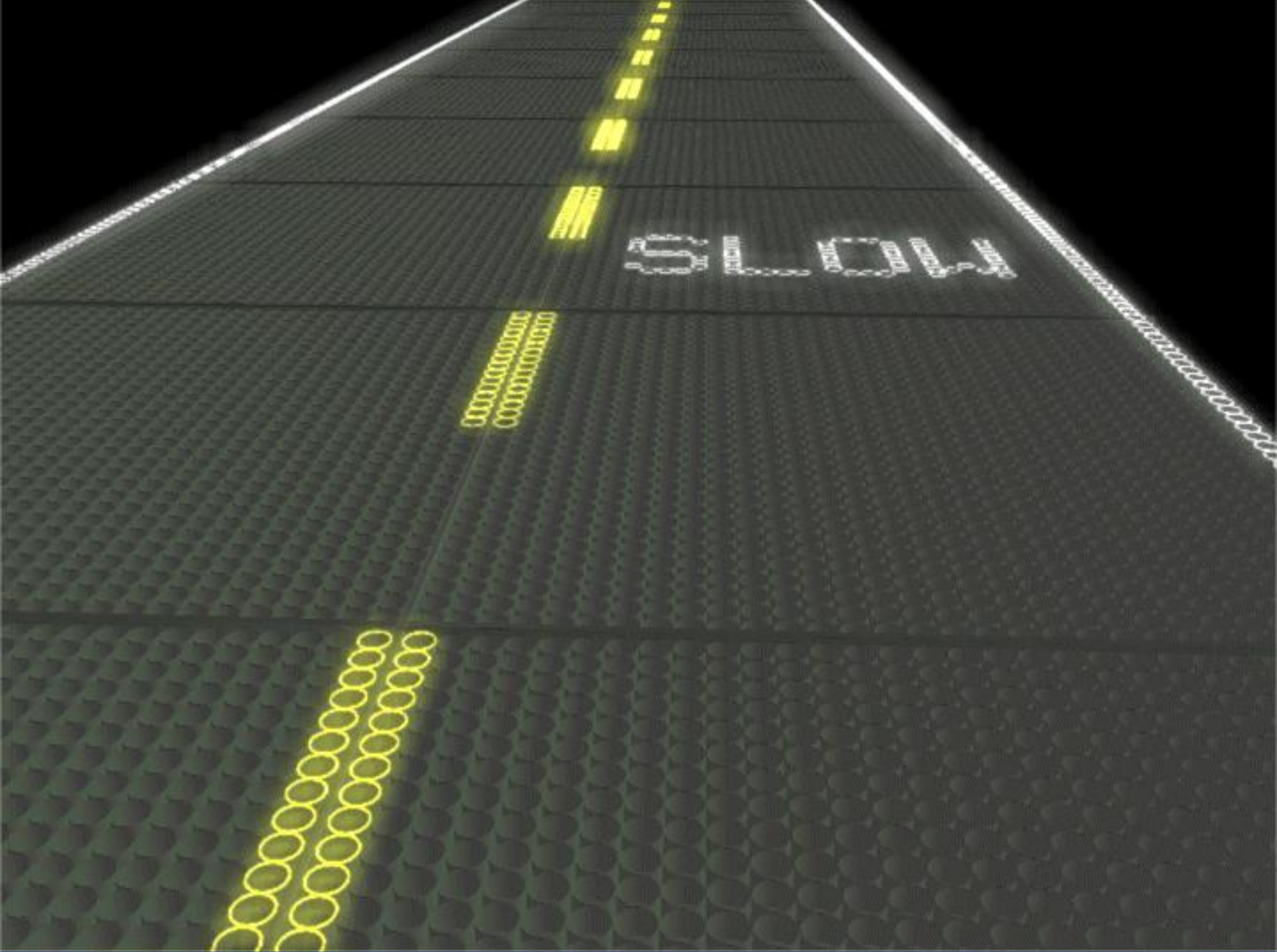
Photovoltaic Method





(2) Solar Roadway Method

- The ultimate purpose is to develop a solar cell system embedded in a composite material structure that can be used on a road surface under severe loading conditions
- The idea is to replace all current asphalt roads with solar panels that collect and store solar energy or to retrofit older roads with this newer technology
- Each individual panel may consist of at least three sub layers: surface layer, electronics layer, and base plate layer


SLOW

- The surface layer needs to be translucent and high-strength, but rough enough to provide sufficient traction, yet still capable of receiving sunlight through to the solar collector cells (e.g., colored epoxy etc.)
  - It also needs to be constructed to handle heavy traffics and the worst conditions as well as being weatherproof to protect the electronics layer beneath it.

- The sub layer will contain a large array of cells, the bulk of which will contain solar-collecting cells with LEDs for "painting" the road surface
  - These cells also contain the "Super" or "Ultra" caps that store the sun's energy for later use

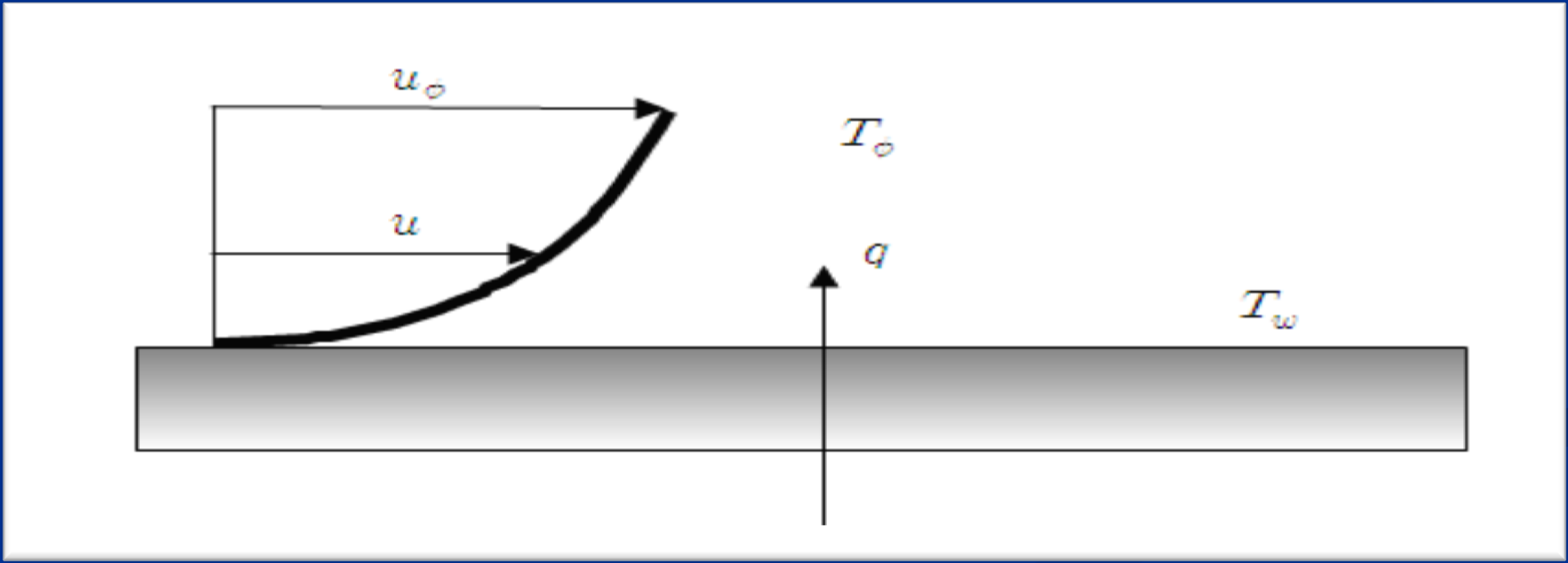
- The base sub layer distributes power and data signals, as well as acting as another waterproof layer to encase the entire panel

(3) Conductive Pipe Method

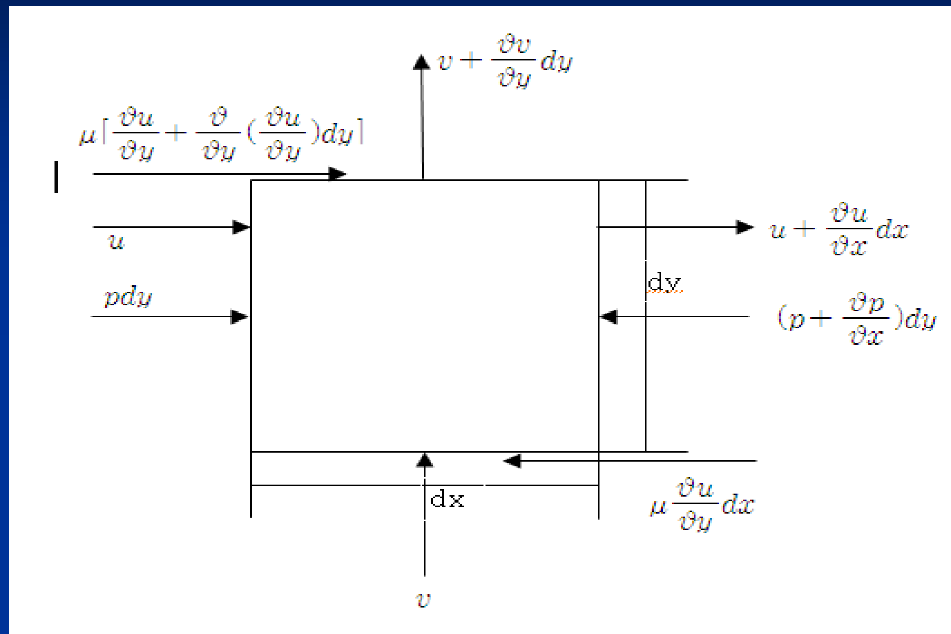
- Pipes embedded within asphalt pavement can cycle water which would heat up as the day goes on because of the absorptive properties of asphalt
- Once heated, this water can be used without further processing to heat buildings or can be processed further through a thermoelectric generator to produce electricity.
- Since the temperature would be already about 140°F (60°C), it may require a small amount of electricity to produce vapor initially.
  - The vapor can be used to make turbines spin to generate electricity, it will become a self-sufficient system.
- Consequently, a pilot study was concentrated on this method.

Newton's Law of Cooling $q = hA(T_w - T_\infty)$

h : heat transfer coefficient	T_w : Temperature at Wall
T_∞ : Liquid (heat transfer medium) Temp.	A : Area



Analytical review of heat transfer of water which pass through plate (or pavement)

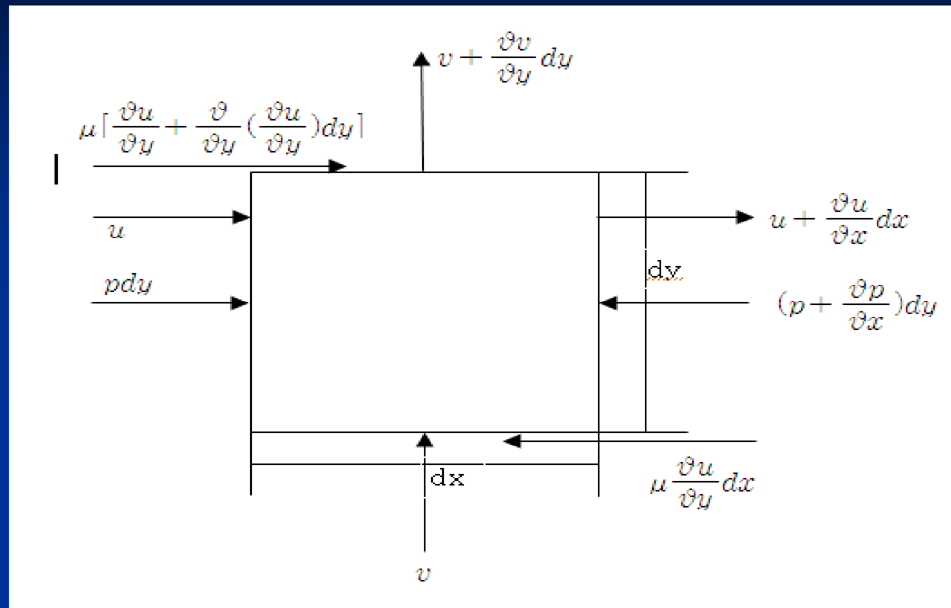


- Continuity Equation at Interface

  Mass Conservation Law

  Mass input $(pudy+pvdx)$ Mass output $(p(u+\frac{\partial u}{\partial x}dx)dy+p(v+\frac{\partial v}{\partial x}dy)dx)$

$$\frac{\partial u}{\partial x}+\frac{\partial u}{\partial y}=0$$ (Continuity differential equation)

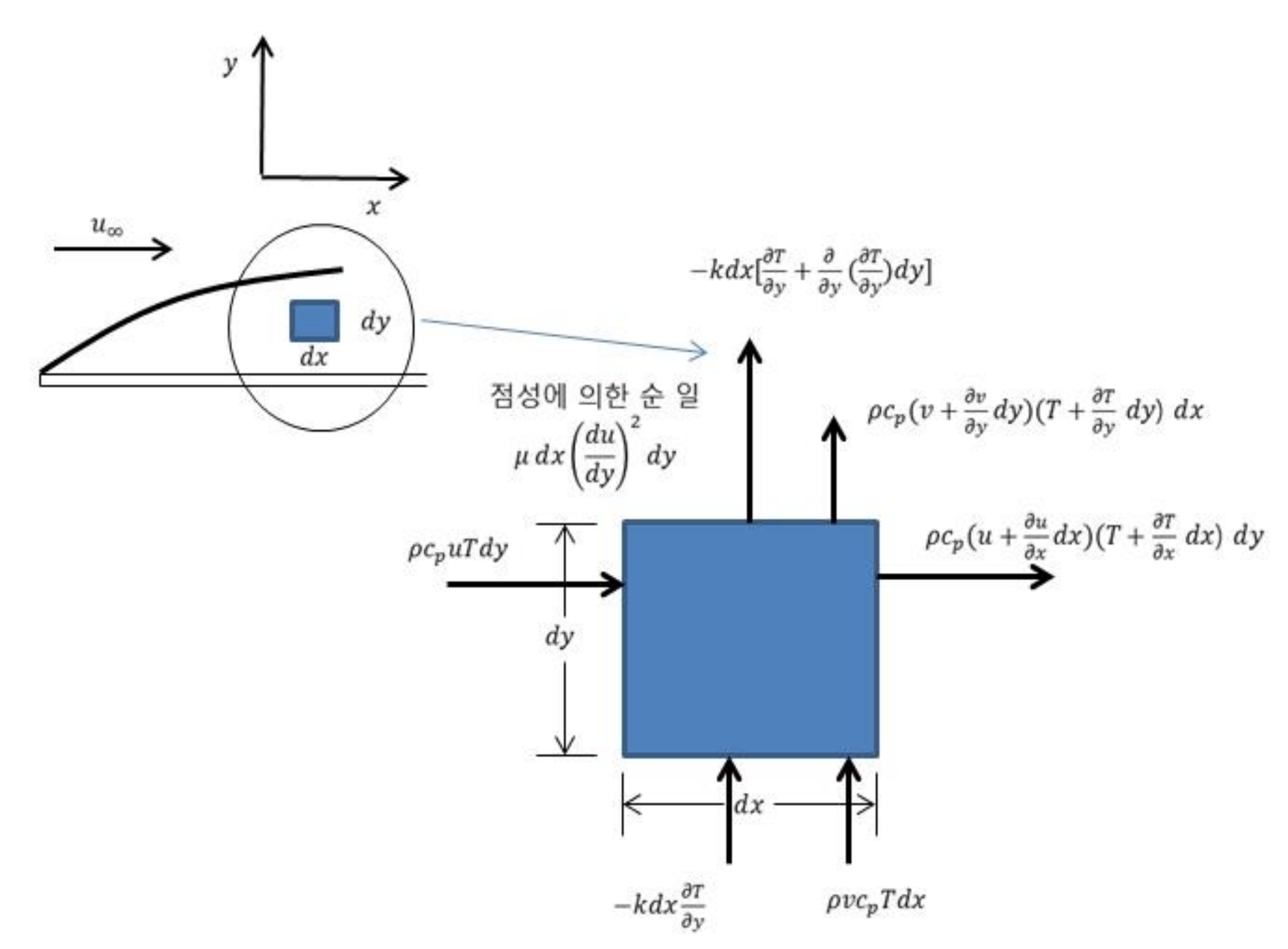


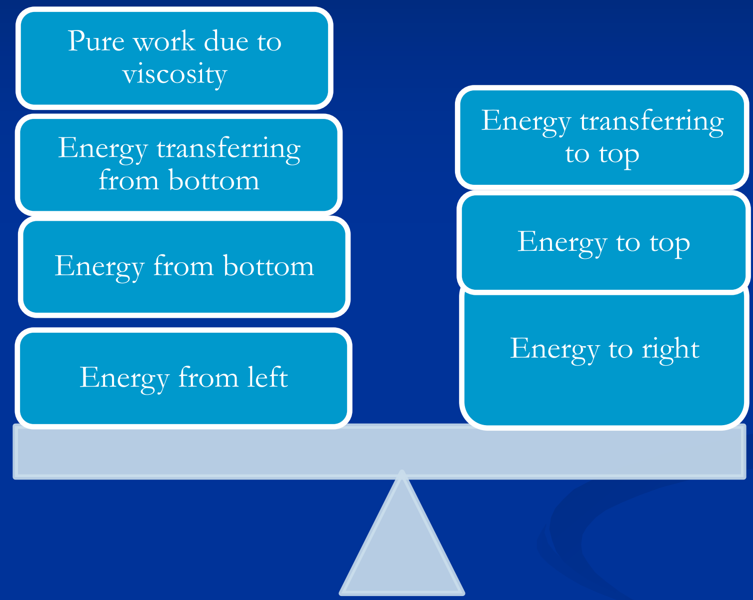
- Work Equation at Interface

  $\sum F_x = X$ direction work increase

$$\mu \frac{\partial^2 u}{\partial y^2} - \frac{\partial p}{\partial x} = p(u \frac{\partial u}{\partial y} + v \frac{\partial u}{\partial y})$$

(Work differential equation at interface)


y
x
u_∞
dy
dx
$-kdx[\frac{\partial T}{\partial y} + \frac{\partial}{\partial y}(\frac{\partial T}{\partial y})dy]$
점성에 의한 순 일
$\mu\, dx \left(\frac{du}{dy}\right)^2 dy$
$\rho c_p(v + \frac{\partial v}{\partial y}dy)(T + \frac{\partial T}{\partial y}dy)\, dx$
$\rho c_p uTdy$
$\rho c_p(u + \frac{\partial u}{\partial x}dx)(T + \frac{\partial T}{\partial x}dx)\, dy$
dy
dx
$-kdx\frac{\partial T}{\partial y}$
$\rho v c_p T dx$



- Energy Differential Equation at Interface

$$u\frac{\partial T}{\partial x}+\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}$$

◆ Temperature Distribution of Pavement Structure

$$\overline{T_w - T_\infty} = \frac{1}{L}\int_0^L (T_w - T_\infty)dx = \frac{1}{L}\int_o^L \frac{q_w^{\cdot\cdot} x}{kNu_x}dx = \frac{q_w^{\cdot\cdot} L/k}{0.6795\,\mathrm{Re}_L^{1/2}\,\mathrm{Pr}^{1/3}}$$

$$\left(Nu_x = \frac{h_x x}{k} = \frac{q^{\cdot\cdot} x}{k(T_w - T_\infty)}\right) \qquad \left(\mathrm{Re}_L = \frac{u_\infty L}{\nu}\right)$$

Where

$T_w = PavementTemperature$

$T_\infty = WaterTemperature$

$Nu_x = NusseltNumber$

$\mathrm{Pr} = \mathrm{Pr}\,andtlCoefficient$

$\mathrm{Re}_L = \mathrm{Re}\,ynoldCoefficient$