Performance Evaluation & Measurement of Heat from the Bituminous Surface by the Addition of Graphene

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Abstract— Bituminous road is also known as flexible pavement and is one of the major transportation media. Surface of the bituminous road is always exposed to the atmosphere, the temperature on the surface will be more due to its colour and the exposure. By addition of graphene to the bitumen the temperature on the surface can be increased. In this concept the graphene is added to the bitumen, performance and extraction of heat is analysed. It is shown that by addition of graphene to the bitumen the temperature on the surface is increased and thus heat energy obtained is harnessed by other means.

Key words: Bituminous Surface, Graphene

I. INTRODUCTION

Fig. 1: Cross Section of Pavement

Flexible pavement can be defined as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade. Water bound macadam roads and stabilized soil roads with or without asphaltic toppings are examples of flexible pavements. By addition of graphene to the bitumen the temperature on the surface can be increased. In this concept the graphene is added to the bitumen, performance and extraction of heat is analysed. It is shown that by addition of graphene to the bitumen the temperature on the surface is increased and thus heat energy obtained is harnessed by other means. Macadam roads.

II. OBJECTIVES

- Performance of evaluation of bituminous mixes by addition of Graphene.
- Measurement of heat from the surface of pavement

III. MATERIALS

A. Bituminous Macadam

Consists of combination of mineral aggregate with bituminous binder ranging from inexpensive surface treatment ¼ in or less thick to asphaltic concrete. For good service throughout the full life bituminous pavement must retain following qualities.

- Freedom from cracking or travelling.
- Resistance to weather including the effect of surface water heat and cold.
- Resistance to internal moisture, particularly to water vapours.
- Tight impermeable surface or porous surface (if either is needed for contained stability of underlying base or subgrade).
- Smooth riding and non-skidding surface.
- Heat a viscous bituminous binder to make it fluid, then in a plant mix it with heated aggregate place and compact the mixture while it is hot.
- Use fluid bituminous binder, mix it with aggregate at normal temperature. Mixing may be done at a plant (plant mix) or on the prepared roadway base (road mix). Spread and compact the mixture at normal temperature.
- Add solvent such as naphtha or kerosene to a viscous bituminous binder to make it fluid with aggregate at normal temperature by either plant or road mix methods. Spread and compact at normal temperature before solvent evaporates.
- Use fluid emulsion of viscose bituminous binder in water, mix it with aggregate at normal temperature by either plant or road mix method. Spread and compact at normal temperature before the emulsion breaks down with its components.
- Spread and compact clean crushed aggregate as for water bound macadam. Over it spray heated dissolved or emulsified bituminous binder which penetrates open areas of the rock and binds the aggregate together. Thus is commonly called “Penetration Method”.
- Spread bituminous binder over the roadway surface then cover it with properly selected aggregate. This is commonly called the “Inverted Penetration Method”.

B. Graphene

Graphene is an allotrope (form) of carbon consisting of a single layer of carbon atoms arranged in a hexagonal lattice. It is the basic structural element of many other allotropes of carbon, such as graphite, charcoal, carbon nanotubes and fullerenes.

1) Properties of Graphene

- It is one atom thick
- Conducts electricity better than silver
- Conducts heat better than diamond
- Two times harder than diamond
- It is 200x stronger than steel

2) Advantages & Disadvantages of Graphene

Major advantages of graphene are;

- It is the thinnest material known and with that also the strongest.
- It consists of a single layer of carbon atoms and is both pliable and transparent.

- It is a superb conductor of both heat and electricity.
- It is used in the production of high speed electronic devices responsible for fast techno logical changes.
- Chemical sensors effective at detecting explosives. Membranes for more efficient separation of gases.
- These membranes are made from sheets from which Nano scale pores have been created.
- Transistors that operate at higher frequency as compared to others.
- It has led to the production of lower costs of display screens in mobile devices by replacing indium based electrodes in organic light emitting diodes (OLED) which also lower power consumption.
- Used in the production of lithium-ion batteries that recharge faster. These batteries use graphene on the anode surface.
- Storing Hydrogen for fuel cell powered cars.

3) Major Disadvantages of Graphene

- Being a great conductor of electricity, although it doesn't have a band gap. Scientists are working on rectifying this.
- The main disadvantage of graphene as a catalyst is its susceptibility to oxidative environments.
- Applications of Graphene in Civil Engineering
- Can be used anywhere concrete would traditionally be used, with particular benefit in environmentally challenging areas where there's the potential to improve the environment and reduce ongoing cleaning costs.
- Graphene-strengthened concrete is likely some way off but researchers are already exploring the potential for self-cleaning or environmentally-improving concrete.
- Right across the construction industry, wherever steel components are used so that the graphene can also be used.
- Lifespan of Roads can also be increased from 6-7 to 12-14 years.
- Resistance to temperature, hence avoids softening in warm temperatures and less cracks in cold temperatures.

C. Temperature Sensors

The most commonly used type of all the sensors are those types of sensors which detect Temperature or heat.
Temperature Sensors measure the amount of heat energy or even coldness that is generated by an object or system, allowing us to "sense" or detect any physical change to that temperature producing either an analogue or digital output. There are many different types of Temperature Sensor available and all have different characteristics depending upon their actual application. A temperature sensor consists of two basic physical types:

1) Contact Temperature Sensor Types

These types of temperature sensor are required to be in physical contact with the object being sensed and use conduction to monitor changes in temperature. They can be used to detect solids, liquids or gases over a wide range of temperatures.

2) Non-contact Temperature Sensor Types

These types of temperature sensor use convection and radiation to monitor changes in temperature. They can be used to detect liquids and gases that emit radiant energy as heat rises and cold settles to the bottom in convection currents or detect the radiant energy being transmitted from an object in the form of infra-red radiation (the sun).

LM35 Temperature Sensor is a contact type temperature sensor used.

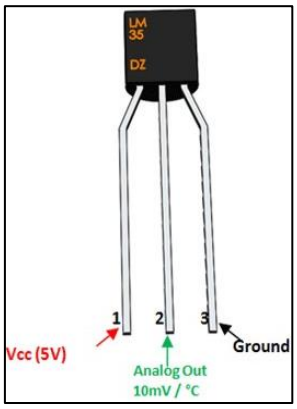

Fig. 2: LM35 Temperature Sensor Pinout Pin Configuration:
LM35 Temperature Sensor Applications

- Measuring temperature of a particular environment
- Providing thermal shut down for a circuit/component
- Monitoring Battery Temperature

IV. EXPERIMENTATION & ANALYSIS

A. Tests on Aggregates

- Crushing Test Property:
- Abrasion Test
- Impact Test
- Shape Tests

IMPACT TEST –	32.4 %
CRUSHING TEST	18.36 %
ABRASION TEST	23.6 %
SHAPE TEST: FLAKINESS ELONGATION	 124% 11.6%

Table 1: Tabulation of Obtained Values of Aggregate Test

B. Tests on Bitumen

- Penetration test
- Ductility test
- Softening Point Test
- Viscosity Test
- Flash and Fire Point Test

V. MARSHALL MIX DESIGN

The mix design determines the optimum bitumen content. This is preceded by the dry mix design.

The Marshall Stability and flow test provides the performance prediction measure for the Marshall Mix design method.

SL NO.	SIZE OF AGGREGATE (mm)	PERCENTAGE (%) USED
1	19	10
2	13.2	32
3	4.75	25

4	2.36	17
5	0.3	8
6	0.075	8
Bitumen Percentage (%)		3.4

Table 2: Aggregate Grading

A. Procedure to Prepare Marshall Mould

- Heat the weighed aggregates and the bitumen separately up to 170^{O}C and 163^{O}C respectively.
- Mix them thoroughly, transfer the mixed material to the compaction mould arranged on the compaction pedestal.
- Give 75 blows on the top side of the specimen mix with a standard hammer (45CM, 4.86KG). Reverse the specimen and give 75 blows again. Take the mould with the specimen and cool it for a few minutes.
- Remove the specimen from the mould by gentle pushing. Mark the specimen and cure it at room temperature, overnight.
- A series of specimens are prepared by a similar method with varying quantities of bitumen and the grapheme content, with an increment of 0.01% (3 specimens).
- Before testing of the mould, keep the mould in the water bath having a temperature of 60^{O}C for half an hour.

B. Marshal Test Procedure

1) Specimens are heated to 60 ± 1 °C either in a water bath for 30 - 40 minutes or in an oven for minimum of 2 hours.
2) The specimens are removed from the water bath or oven and place in lower segment of the breaking head. The upper segment of the breaking head of the specimen is placed in position and the complete assembly is placed in position on the testing machine.
3) The flow meter is placed over one of the post and is adjusted to read zero.
4) Load is applied at a rate of 50 mm per minute until the maximum load reading is obtained.
5) The maximum load reading in Newton is observed. At the same instant the flow as recorded on the flow meter in units of mm was also noted.

Binder Content	Proving Ring Reading		Dial Gauge Reading	
	P.R Division	Div X L.C 0.002	D.G Division	Div X L.C (0.01)
3.5	0	0	0	0
	1025	2.05	910	9.1
3.8	0	0	0	0
	1115	2.23	990	9.9
4	0	0	0	0
	1170	2.34	1040	10.40
4	0	0	0	0
	1175	2.35	1048	10.48

Table 3. Tabulation of Conventional Marshall Mould Test

Bitumen Content/ Graphene Content	Proving Ring Reading		Dial Gauge Reading	Div X L (0.01)
(0.187gms) 4/0.015	0	0	0	0
	1294	2.588	1132	11.32
(0.312gms) 4/0.025	0	0	0	0
	1375	2.75	1186	11.86
(0.0437gms) 4/0.035	0	0	0	0
	14.34	2.928	1218	12.18

Table 4: Tabulation Graphene Added Bitumen Marshall Mould Test

- Observation:

% of Bitumen	voids in Bitumen (VFB)
3.5	62.69
3.8	62.85
4	63.7

Table 5 Percentage of Air voids in Bitumen

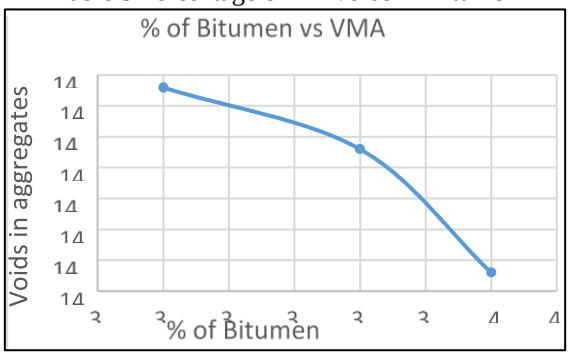

Fig. 3: Percentage of Bitumen Vs Voids in Aggregate

% of Bitumen	Air voids
3.5	5.57
3.8	5.51
4	5.31

Table 6: Percentage of Bitumen and Vmf

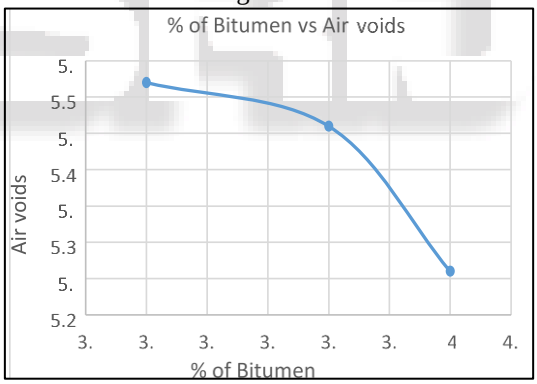

Fig. 4: Percentage of Bitumen & Air Voids

% of bitumen	voids in aggregate (VMA)
3.5	14.93
3.8	14.83
4	14.63

Table 7: Percentage of voids in Aggregates

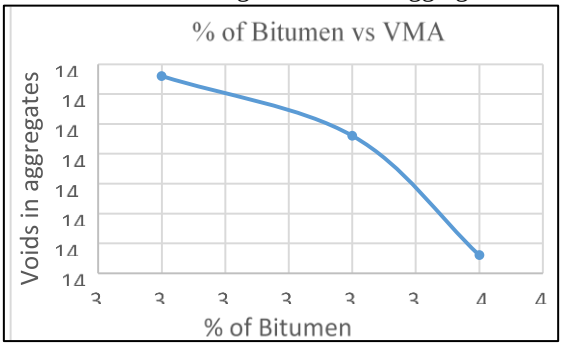

Fig. 5: Percentage of Bitumen and Voids in Aggregate

ATMOSPHERIC TEMPERATURE IN C˚	CONVENCTIONAL BITUMEN IN C˚	GRAPHENE ADDED 0.015% (C˚)	GRAPHENE ADDED 0.025% (C˚)	GRAPHENE ADDED 0.035%(C˚)	TIME
30	41	45	48	51	10AM
32	42	46	51	53	11AM
33	42	46.5	51	54	12PM
35	46	50	53	56	1PM
37	49	53	56	59	2PM
36	47	51	54	56	3PM
34	44	47	51	54	4PM

Table 8: Tabulation of Temperature Measurements

VI. CONCLUSION

- Performance of bituminous graphene mixes is enhanced
- Measurement of heat entrapped on the pavement surface
- Extraction of heat from the surface of pavement thereby harnessing the natural Solar Energy and can be transformed to other forms.
- If graphene is added to bitumen by 0.015%, the temperature is observed to increase by 20-25%
- If graphene is added to bitumen by 0.025%, the temperature is observed to increase by 25-30%
- If graphene is added to bitumen by 0.035%, the temperature is observed to increase by 30-

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