DESIGN OF ECO FRIENDLY PERMEABLE PAVEMENT WITH EPOXY RESIN AND TITANIUMDIOXIDE OVERLAY ALONG WITH GGBS CONCRETE BASE

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Abstract-Permeable pavement consist of concrete structures with high porosity that allow water to percolate through them. It is usually made with large aggregates with almost no fine aggregates. It is widely used in parking areas, areas with moderate traffic, residential places. It was first used in 1800 in Europe for its cost efficiency. The main disadvantage is that it needs to be cleaned regularly by wetting the surface and vacuum sweeping which reduces its efficiency and lifetime, to prevent this we have designed a composite pervious pavement using GGBS concrete as base and Epoxy resin at the top for aesthetic and environmental purpose. The additional layer of titanium dioxide absorbs airborne pollutants reducing strains on ecosystem.

Keywords: Epoxy Resin, Titanium dioxide, GGBS, Triethanolamine

I-INTRODUCTION

Permeable pavement reduces the runoff volume and it prevents bank erosion, it also reduces the heavy floods caused during monsoon. The quality of underground aquifers increases and heat island effect is significantly lowered. It reduces the need for huge storm water infrastructure and also the cost required in waste water management. They must be designed to provide adequate structural capacity to withstand the vehicular loading and also manage the storm water flowing into the soil. When properly designed permeable pavement can infiltrate as much as 60% to 80% of rainfall. While initial cost of construction is higher than conventional pavement they are eliminated by the need to construct storm drains.

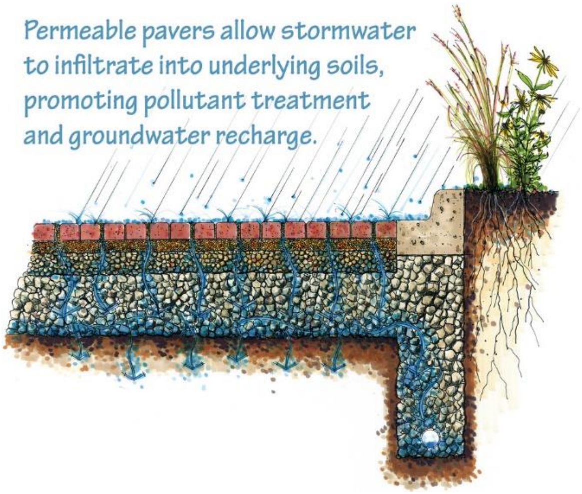

FIG NO 1: CONCEPT OF PERMEABLE PAVEMENT

II-CONCRETE BASE USING GROUND GRANULATED BLAST FURNACE SLAG (GGBS):

Ground Granulated Blast Furnace Slag (GGBS) is a by-product obtained from manufacturing process of iron from blast furnace. The slag is initially taken as a molten liquid and rapidly quenched in large quantities of water to obtain GGBS. Being a waste by product using it effectively promotes greener environment and at the same time the strength of the concrete also increases.

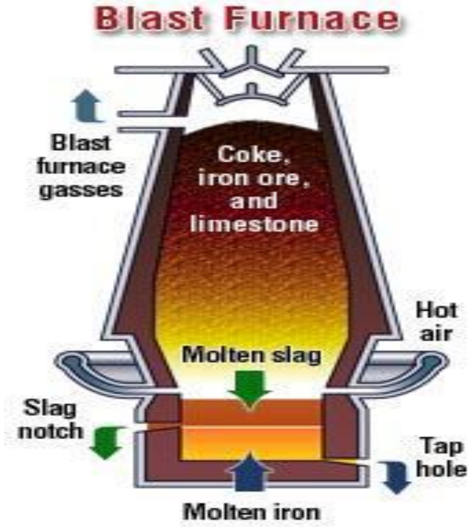

FIG NO 2: GGBS PRODUCTION

The chemical composition of GGBS is

Calcium oxide – 30-45%

Silica-30-38%

Alumina-15-25%

Magnesium-4-17%

Manganese-1-5%

The physical properties are

Colour: White

Specific gravity:2.9

Bulk Density: 1200kg/m^3

It is used for its superior durability thereby extending the life of structures. It is combined with Ordinary Portland Cement with GGBS content ranging typically from 30%-70%. Concrete made with GGBS has increased initial setting time depending on the amount of GGBS added in the mix. It results in significant lower heat of hydration and increased workability of concrete. It has high resistance towards chlorides thus reducing the risk of corrosion caused to reinforcements. It also has high resistance towards sulphate attacks.

FIG NO 3: PLACING OF GGBS

GGBS concrete has a increased slump value when compared to Portland concrete making it easier to place and compact while pumping. It is a fine powder that causes irritation to the eyes and respiratory system if proper care is not taken.

III-TRIETHANOL AMINE (TEA) AS ADMIXTURE:

The important aspect of cement based materials is its initial setting time which is critical for scheduling the operation also for the process of transporting, placing, compacting and levelling process. Accelerators are chemical admixtures that are used to reduce the initial setting time of concrete, usually accelerators that are free of chlorides and alkali is used, as alkali causes health degradation and chlorides corrode the steel reinforcement.

Triethanolamine is used as a setting time regulator for hydration of cement. TEA has its own unique character such that it can either accelerate or retard the setting time depending upon the amount used. It is respectively classified as light accelerator, retarder and strong accelerator.

Triethanolamine is a strong base and a colourless compound. It is produced from the chemical reaction of ethylene oxide and aqueous ammonia.

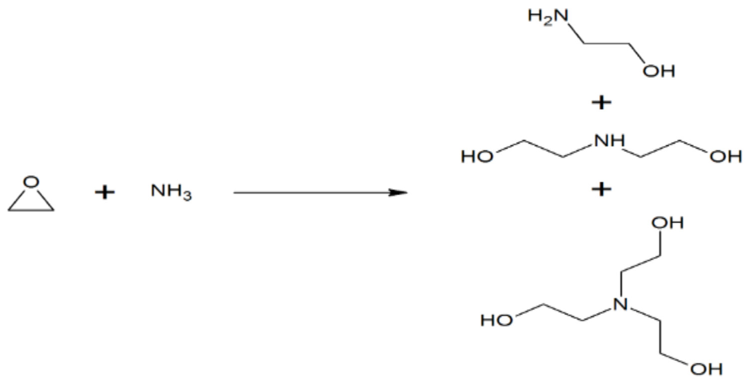

FIG NO 4: TRIETHANOLAMINE

PROPERTIES OF TRIETHANOLAMINE:

Chemical formula:$C_6H_{15}NO_3$

Molar mass:149.19 gm mol^{-1}

Odour: Ammoniacal

Density:1.1124gmL^{-1}

Melting point: 21.6°C

Boiling point: 335.40°C

Solubility in water: Miscible

Vapour pressure: 1Pa

Acidity: 7.74pKa

APPLICATIONS:

It is used in the manufacturing of surfactants such as emulsifier.
Cement production: It is used as organic additive for facilitating the grinding process by preventing agglomeration.
The other applications are it is employed in cosmetics and drugs, medicines, in photography, holography and electro less plating
TEA if not properly handled causes allergic dermatitis and respiratory problem. It also causes liver tumour in females.

IV-EXPERMIMENTAL ANALYSIS

The materials used in this research are Ordinary Portland Cement of 53 grade having compressive strength of 54.9 MPa after 28 days, satisfying the requirements of IS:12269-2013 was used. The specific gravity of cement was found to be 3.1. Fine aggregates are obtained from river sand and coarse aggregates of crushed granites stone confirming to IS:383.

Alkaline activator solution is used. It is the combination of solution of sodium hydroxide and sodium silicate besides distilled water. The role of the solution is to activate the geo polymeric materials containing silica and aluminium such as GGBS.

Triethanolamine is used as a chemical admixture in various proportions of dosages 200ppm, 1000ppm and 4000ppm to study its various effects on the setting time of concrete.

FINENESS MODULUS OF COARSE AND FINE AGGREGATES:

Fineness modulus of aggregates denotes the size of the particle by an index member. It is calculated by sieve analysis with standard sieves.

The cumulative percentage retained on each sieve is added and percentage of material passing is determined.

For coarse aggregates the sieve sizes of 40mm, 37.5mm, 25mm, 13.2mm, 12.5mm, 11.2mm, 10mm, 4.75mm, 2.36mm was used. It has a fineness modulus of 6.5.

For fine aggregates the sieve sizes of 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 0.7mm, 0.3mm, 0.15mm was used. The fineness modulus was found to be 2.60.

FIG NO 5: FINENESS MODULUS OF COARSE AGGREGATE

FIG NO 6: FINENESS MODULUS OF FINE AGGREGATE

SPECIFIC GRAVITY TEST ON COARSE AND FINE AGGREGATES:

Pycnometer is used to determine the specific gravity of aggregates. Fine aggregates passing through 4.75mm IS sieve and coarse aggregates of size 20mm were taken and oven dried and weighed. The mass of the pycnometer is determined and known quantities of aggregates is fed into and filled with water up to its top with cap screw on. Care is taken such that air is completely removed and the weights are determined.

Specific gravity of fine aggregates was found to be 2.69.

Specific gravity of coarse aggregates was found to be 2.82.

FIG NO 7:PYCNOMETER WITH COARSE AGGREGATES

FIG NO 8: PYCNOMETER FILLED WITH WATER

FIG NO 9: PYCNOMETER WITH FINE AGGREGATES

WATER ABSORPTION TEST ON COARSE AGGREGATES:

The aggregates are oven dried at temperature of 110°C for 24 hours. The aggregate is cooled to room temperature and weighed. The dried coarse aggregate is immersed in clean water at 27°C for 24 hours. The coarse aggregate is removed from water and wiped out of traces of water with a cloth. Within three minutes of removal the weight of coarse aggregate is found and the percentage of water absorption is determined.

The water absorption of the coarse aggregate is 0.62%.

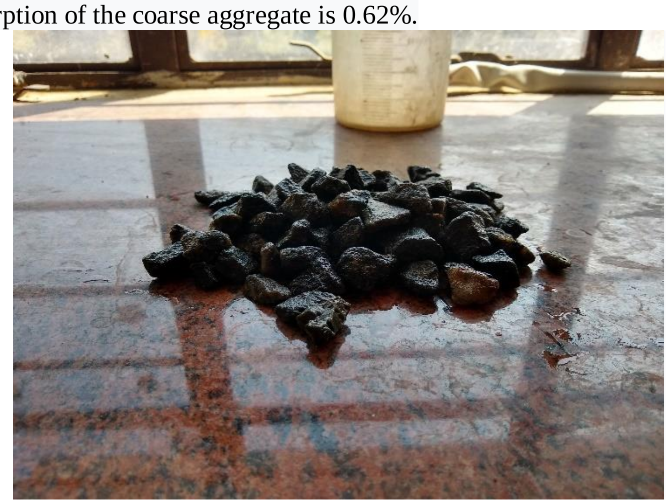

FIG NO 10: WATER ABSORPTION TEST ON COARSE AGGREGATE

MIXING OF MATERIALS:

- The test is done for M20 grade concrete of ratio 1:1.5:3.
- 3.9 kg of OPC is mixed with 2.1 kg of GGBS.
- Sodium hydroxide and sodium silicate is mixed in the ratio of 1:2.5 and alkaline activator solution is prepared.
- The alkaline activator solution to GGBS ratio is 0.35.
- The water cement ratio used for mixing is 0.45.
- The materials are thoroughly mixed in a drum mixer and care is taken such that the material is homogenous.
- The mix is evenly split into three parts and triethanolamine is added in dosages of 200ppm, 1000ppm and 4000ppm.
- The concrete is cast into cubes of size 150mm x 150mm x 150mm.

FIG NO 11: MATERIALS USED IN THE CONCRETE MIX

INITIAL SETTING TIME

- About 400 g of cement is taken and prepared a neat cement paste with 0.45 of water by weight of cement.
- Gauge time is kept between 3 to 5 minutes. The stop watch is started at the instant when the water is added to the cement. Record this time (t_1).
- Fill the Vicat mould, resting on a glass plate, with the cement paste gauged as above. The mould is filled completely and smooth off the surface of the paste making it level with the top of the mould. The cement block is called test block.
- Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle.
- Lower the needle gently until it comes in contact with the surface of test block and quick release, allowing it to penetrate into the test block.
- In the beginning the needle completely pierces the test block. Repeat this procedure i.e. quickly releasing the needle after every 2 minutes till the needle fails to pierce the block for about 4 mm measured from the bottom of the mould. Note this time (t_2).
- The initial setting time is given by t_2-t_1.

FIG NO 12: INITIAL SETTING TIME OF GGBS CEMENT

- The setting time of GGBS cement for a dosage of 200ppm of triethanolamine was found out to be 93 minutes
- The setting time of GGBS cement for a dosage 1000ppm of triethanolamine was found out to 113 be minutes
- The setting time of GGBS cement for a dosage 4000ppm of triethanolamine was found out to be 68 minutes

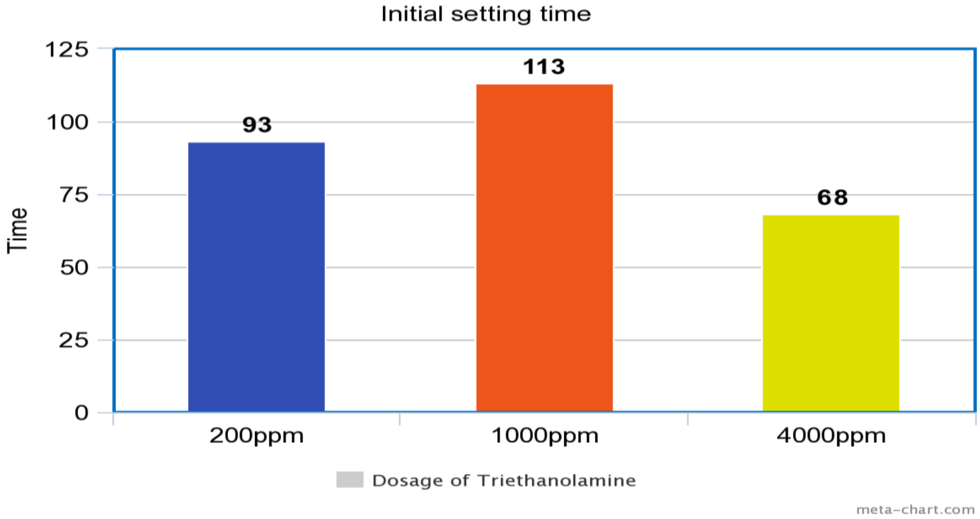

FIG NO 13: GRAPHICAL REPRESENTATION OF SETTING TIME

The different natures of triethanolamine as accelerator, retarder and strong accelerator in various dosages are clearly depicted.

COMPRESSIVE STRENGTH TEST:

The compressive strength of concrete is given in terms of the characteristic compressive strength of 150 mm size cubes tested at 7 days. The specimen to be tested is placed in the machine in such a manner that the load shall is applied to opposite sides of the cubes as cast. The specimen to be tested is carefully aligned in the centre and packing plates should not be used. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq.cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load the specimen can withstand is determined and the appearance of the cracks on the specimen is noted for any unusual failures.

FIG NO 14: COMPRESSIVE STRENGTH TEST

- The characteristic compressive strength of Ordinary Portland cement after a period of 7 days was found out to be 15 N/mm^2
- The characteristic compressive strength of GGBS concrete mix with replacement ratio 30% and 200ppm of triethanolamine was found out to be 18N/mm^2
- The characteristic compressive strength of GGBS concrete mix with replacement ratio 30% and 1000ppm of triethanolamine was found out to be 16N/mm^2
- The characteristic compressive strength of GGBS concrete mix with replacement ratio 30% and 4000ppm of triethanolamine was found out to be 21N/mm^2

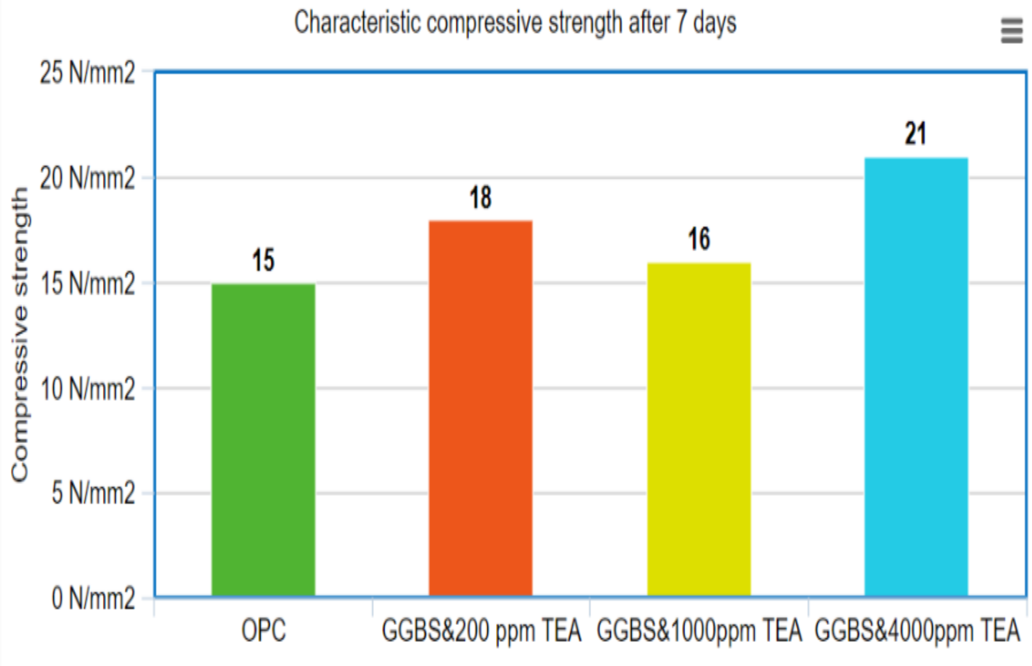

FIG NO 15: COMPARISON OF COMPRESSIVE STRENGTH AFTER 7 DAYS

V-DESIGN OF ECO FRIENDLY PAVEMENT

The pavement without any doubt is the most used element in public spots. It is subjected to stresses both static and dynamic, chemical actions, environmental detrimental effects and so on. The main considerations to be taken for floor design are its structural design, quality of materials, protection from external factors, conservation of environment and maintenance.

EPOXY AS PERMEABLE PAVER:

The most commonly used solutions for pavements are epoxy, polyurethane and metacrylate. Among these epoxy has the greatest advantage due to its chemical and mechanical resistance, easy maintenance and most importantly innumerable aesthetic possibilities taking into account the diversity of types of finishing that can be done with it. The performance of this type of pavement is based on the ideologies of human factor.

Epoxy is a thermo-set material that offers the performance and durability needed, and it is the perfect choice for permeable paver. There are several types of epoxy resin with its own unique advantages, but all epoxy resins are basically very hard in nature and bonds fully with concrete. It has a cure time of 12-24 hours depending on the temperature.

TITANIUM DIOXIDE OVERLAY:

Urban trees have a usual job of cleaning the air pollution but nowadays various ideologies such as green walls and biofilteration have been introduced.

The potential use of titanium dioxide over epoxy pavers turns them into battle station for clean air. Titanium dioxide is a highly versatile compound in fighting pollution. Its capacity to fight against pollution comes from its stature as a photo catalyst. When exposed to ultraviolet rays from sun it accelerates many chemical reactions including the oxidation of smog, nitrogen oxides and various organic compounds. Nitrogen oxides are turned into soluble nitrates, and volatile organic compounds into fatty acids.

GGBS CONCRETE AS BASE:

GGBS is used as base due to its protection against sulphate and chloride attacks. It has successfully replaced sulphate resisting Portland cement due to its high efficiency and low cost. The use of GGBS will also increase the load carrying capacity of the pavement and increase the life of the structure. GGBS concrete has a gradual heat of hydration generating lower heat when compared to conventional concrete, which in turn reduces the thermal gradients in the concrete preventing the development of micro cracking. Dirt does not adhere to GGBS concrete as compared to Portland cement thus eliminating the need for expensive maintenance.

NEED FOR ECO FRIENDLY PAVEMENT:

Over the last few years' cities and suburbs have become larger and densely populated, areas that were used to be covered by vegetation are now replaced with infrastructures. The absence of these natural surfaces have greatly disrupted the natural cycle of water. This has caused cities to have problems of excessive storm water runoff, degradation of natural water quality, need for expensive large storm drains. These cause risks to the sustainable development of the cities and it requires a viable solution.

Permeable pavements allow water to directly percolate into the ground. It reduces the strains caused on storm water drains by reducing the runoff volume. It also reduces the heat island effect i.e. the urban area significantly warmer than surround areas due to increased infrastructures and human activities. The additional layer of titanium dioxide also plays a vital role in the reduction of air pollutants thus promoting a greener future.

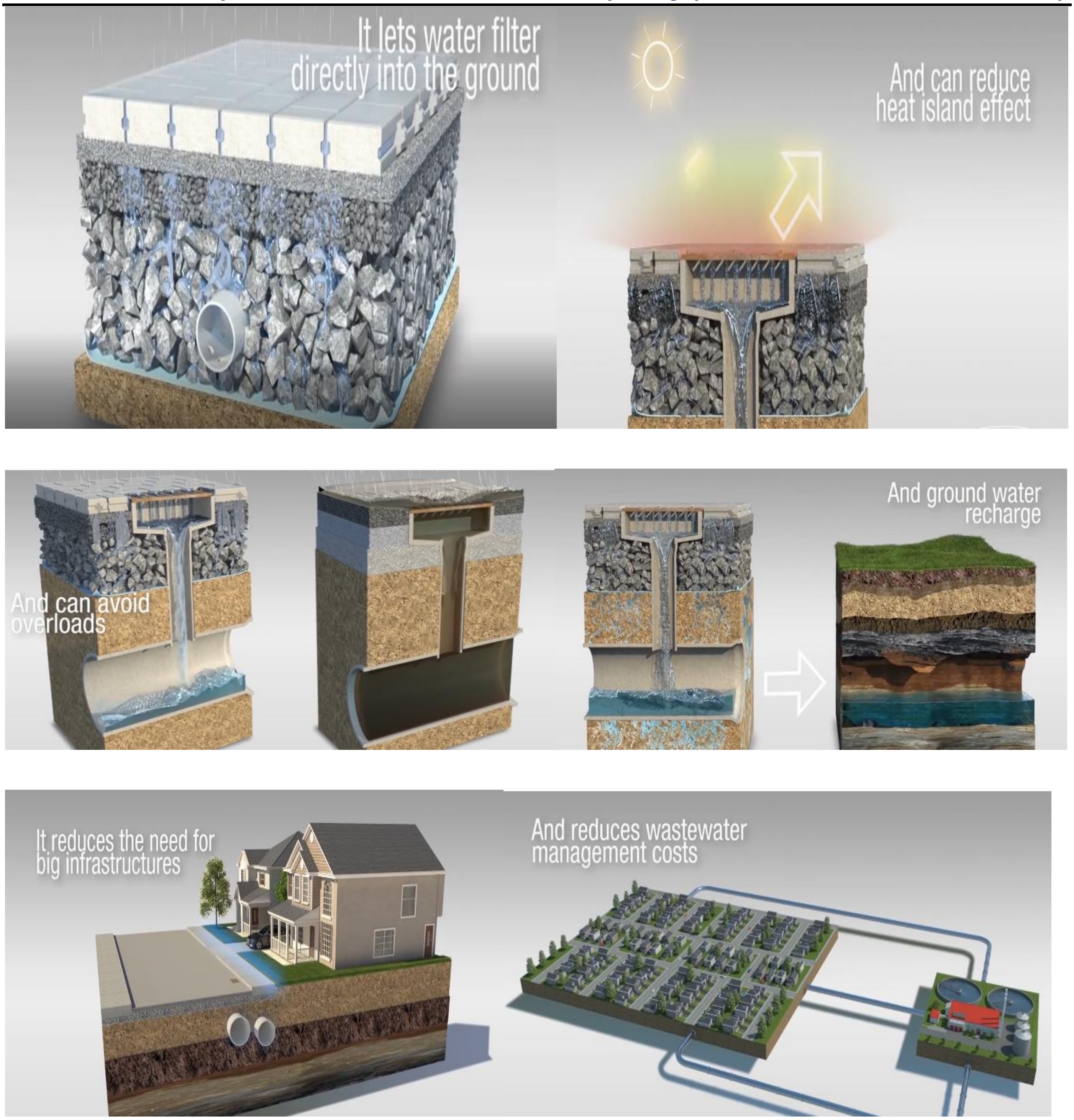

FIG NO 16: ADVANTAGES OF ECO FRIENDLY PAVEMENT

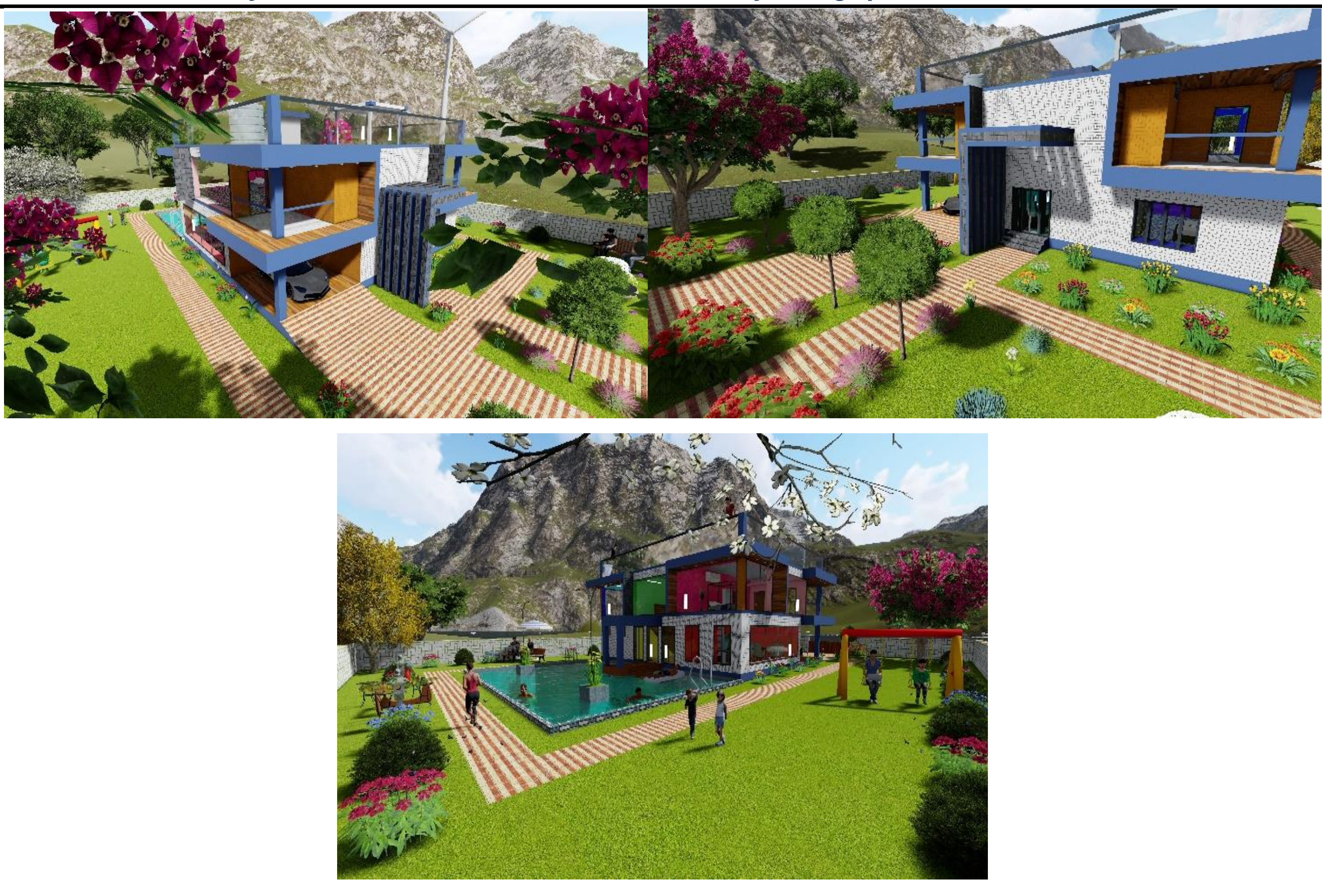

FIG NO 17: RENDERED IMAGES OF ECO FRIENDLY PAVEMENT USING LUMION PRO 8.0

VI- CONCLUSION

Convential concrete pavements are becoming a source of concern as it causes problems to the natural water cycle process and it also causes degradation to ecosystem. Time has come to move on to a more cleaner and greener tomorrow and permeable pavement holds the key for sustainable development. The enhanced usage of titanium dioxide overlay on epoxy resin blocks ensures air pollutants are put in check along with the problems faced with runoff water and polution to ground water aquifiers.

VII- REFERANCES

- Concrete technology theory and practice by M.S.Shetty
- Concrete technology by Gambhir
- IS:12269-2013 (Ordinary Portland Cement grade 53 specification)
- IS:383 (Specification for coarse and fine aggregates from natural source for concrete)