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Future Solar Roadway on Traditional Road

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ABSTRACT

Construction of highway with bitumen and concrete are the most acceptable materials till now. These roads have a lack of maintaining their physical properties till design life. We found holes in the roads everywhere after the rainy season due to heavy load transport vehicles. This unacceptable hole causes comfort, accidents, vehicular damage etc. So the next level of road construction came out as the Solar Roadway construction. These roads are very comfortable, accidental damages are very low, water resistant, electricity generator, smart and with proper physical characteristics of general roads. But this road needs special rigid concrete pavement. The cost of laying the solar roadway is thus very expensive as we have to withdraw all the road materials previously constructed and reconstruct the solar roadway pavement. And the time requirement is very high in this reconstruction of road pavement.

So I have taken this project "Future Solar Roadway on Traditional Road". This project will help us to construct the solar road on traditional concrete or asphalt roads with very low cost and less time of construction. The new type of road surface will give facilities same as the proposed special solar road.

Keyword: Future, Solar, Road, Construction, Free Low-Cost Energy, Smart Way, Safer Road, Digital World.

I.INTRODUCTION

1. I BASIC PROPERTIES OF SOLAR ROADWAY PANELS

Today's everything is going to be smart such as Smartphones, Smart Homes, Smart Cities, Smart Cars and so on. A new addition to the Smart families is Solar Roadway. Solar Roadway (SR) is a modular system of specially engineered solar panels that can be walked and driven upon. The panels contain LED lights to create lines and signage without paints. They contain heating elements to prevent snow and ice accumulation. The panels have microprocessors, which make them intelligent. This allows the panels to communicate with each other, a central control station, and vehicles. We will be able to charge electric vehicles with clean energy from the sun. These panels are made of glass but not ordinary glass. Solar roadway panels are made of specially formulated tempered glass, which can support the weight of semi trucks. The glass has a tractioned surface which is equivalent to the asphalt. The goal of this project is to modernize the infrastructure with modular, intelligent panels while producing clean renewable energy for homes and businesses in minimum cost.

1.2: Why Solar Roadway

The primary purpose of Solar Roadways is to generate clean renewable energy on roadways and any other surface that can be walked or driven upon. That would include parking lots, sidewalks, driveways, tarmacs, plazas, bike paths, playgrounds, garden paths, pool surrounds, courtyards and the like.

There are many longstanding uses for solar power, which are terrific. The SR concept takes solar technology to a new level. The idea is to collect the substantial solar energy which hits these surfaces but is currently not being utilized. In this way, they will have a dual purpose: modern infrastructure + smart power grid.

1.3: Energy Production

Using very conservative numbers, calculations indicate that if all driving and walking surfaces in India were converted to Solar Roadway panels, they could produce over four times the electricity used in India (total electricity consumption was 939 billion kWh during 2014-15). In fact, just the "lower 48" could almost produce enough electricity to supply the entire world.

1.3.1: Calculation of Energy

Total Highway in India is approximately 2637937 mile. If we consider an average of 4 lanes= 28 ft (0.005 miles) wide roadway, then total area covered by roads will be 2637937*0.005=13190 square mile. Removing 1/3 for rooftops and that leaves 8794 square miles of roads, parking lots, driveways, playgrounds, bike paths, sidewalks, etc., to work with.

If these impervious surfaces were replaced with Solar Road Panels, how much electricity would we produce?

In labs, solar cell efficiency has exceeded 44-percent, but they do not cost feasible yet. So For calculations, commercially available solar panels are used, which are cost competitive.

The efficiency of 18.5% is commonly available, so for the calculations, the following (conservative) assumptions have been made:

Solar cells have an 18.5% efficiency. There is an average of only 4 hours of peak daylight hours per day (4 x 365 = 1460 hours per year).

Sun power offers a 230 Watt solar panel rated at 18.5% efficiency. Its surface area is 13.4 square feet. If the entire 8794 square miles of impervious surfaces were covered with solar collection panels, then:

((8794 mi^2) x (5280 ft / mi^2)) / (13.4ft^2/230W) =

((8794 mi^2) x (27,878,400 ft^2 / mi^2)) / (13.4ft^2/230W) =

(245662649600 ft^2) / (13.4ft^2/230W) = 4,208,015,627,463 Watts or over 4.21 Billion Kilowatts

Considering only the average of 4 hours of peak daylight hours (1460 hours per year), this gives: 4.21 Billion Kilowatts x 1460 hours = 6146 Billion Kilowatt-hours of electricity.

For fairness, we subtract 31 percent from our totals since we can't angle roads and parking lots:
6146 Billion Kilowatt-hours x 0.69 = 4241 Billion Kilowatt-hours.

1.4: Power Supply Management

Currently, power lines are either up on poles where they are susceptible to damage from storms, or buried in the ground. If they are up on poles, the wind can knock them down. Ice can collect on cables, causing breakage and power outages. Utility workers have to climb poles to access them for repair and are sometimes hurt. If the lines are buried, the utility workers have to dig them up with shovels, not knowing exactly where they are. Gas lines are often nearby, posing a danger. Solar Roadways Cable Corridors offer a solution. There are two sections: one for cables and one for water. The cable section offers a “home” for cables where they are safe from environmental hazards and easy for utility workers to access (locked to others). Power outages could become a rare event.

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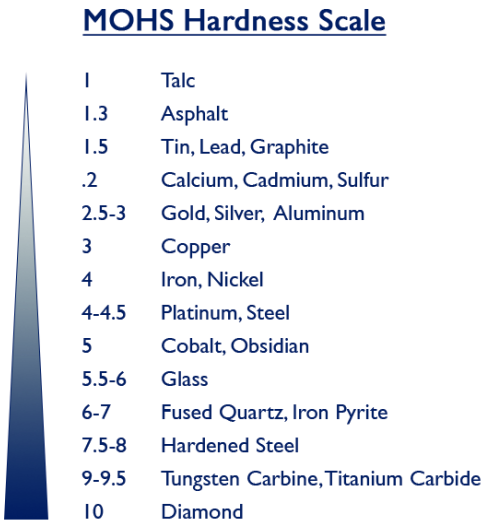
Photo- normal power supply management

1.5: Smart Grid

Solar Roadways can replace all current centralized power stations and become the smart grid for each nation, with sufficient installed infrastructure. The Cable Corridor remedies the need for unsightly utility poles. The Cable Corridor that runs alongside Solar Roadways can provide a home for utility lines. Power lines, telephone lines, etc. can be placed within the Cable Corridor. This can significantly reduce outages from storm events. This would also provide easy access to all systems, making maintenance and repair simple. The safety of utility workers who must now climb poles and dig for cables buried in the ground would be increased. Landscapes would be unmarred. Power can be generated everywhere - from all walking and driving surfaces. A decentralized system offers protection from outages. Much of the power is used near the power source (e.g.- driveways power homes, parking lots power businesses, etc.) Excess power produced by SR can feed surrounding areas. Even a disruption in the grid (road) will cause significantly fewer outages. Since both sides of the now damaged road still produce electricity, fewer lose power. All walking and driving surfaces supply power to homes and businesses. Less energy needs to be transported over long distances, resulting in less energy loss. It also means smaller cables are required, saving materials (and therefore costs). SR produces the power closer the point of use. Some have expressed concerns about theft. Each panel has its own microprocessor, which communicates wirelessly with the surrounding panels. They monitor one another for malfunctions or problems. If someone were able to pull a panel out of the road and load it on a truck, the stolen panel would continue communicating with all of the other panels in the road. The road would know exactly where it was and how fast it was moving. The panel would literally lead the authorities to the thief.

1.6: Durability and Disasters

Solar Roadways is specifically engineered for road use. SR panels are designed to last a minimum of twenty years. Solar cells are the limiting factor, they can continue to work up to 30 years, but they are less efficient toward the end of their life cycle. Each panel can withstand great variations in temperatures. The electronic components are made to endure high temperatures. The microprocessors can endure temperatures from -40^{0}F (-040^{0}C) up to 257^{0}F (125^{0}C). Each Solar Road panel is hermetically sealed to protect the electrical components. The panels can be completely submerged, and the electrical components will be protected. This is a preventative measure for flash flooding. SR can shield against an EMP as with any other type of electromagnetic radiation: with shielding and proper grounding, which can mitigate or eliminate the effects of EMP. Shielding places a conductive surface between the source of the EMP and the electronic components. When the harmful radiation encounters a conductive surface, energy is transferred from the magnetic field into the conductive surface and shunted safely to the ground. This leaves less of the energy available to be transferred into the circuit. Protection diodes, which provide a low impedance path around low voltage circuitry, can also be utilized to minimize the effects of inductive voltage spikes.



1.7: Properties of Glass used in Solar Panel

Solar Roadway panels are made of tempered (safety) glass. Glass was chosen for its hardness, strength, durability, and transmittance. SR glass is textured to create proper traction for vehicles and pedestrians. The glass passed traction tests, load tests, and impact resistance tests at university civil engineering labs around the country. Each unit is made of top and bottom glass panels, with the other components such as solar cells and LED lights enclosed between. One major difference one will notice when comparing SR glass panels to

traditional asphalt roads is aesthetics. The hexagonal panels are quite a work of art and will dramatically beautify roads, parking lots, walkways, patios, bike paths, etc. Solar Roadways chose the hexagonal shape for extra stability to wear and flexibility in installing curves, hills, and odd shaped installations. There are half and quarter panel shapes as well. Eventually, other shapes will be added to the SR catalog of options. Unlike asphalt, SR panels are impervious to potholes. The repair of potholes is an enormous expense, the source of danger and an unnecessary inconvenience to motorists.

1.7.1: Weight Limits

The glass has undergone both 3D Finite Element Method analysis and actual physical load testing at civil engineering labs. The results showed that Solar Roadways can handle trucks up to 250,000lbs (113,398kg). Originally, it was thought that Solar Roadways panels would need to support only about 80,000lbs (36,287kg), the maximum legal limit for a semi-truck. Upon further research, it became apparent that since logging trucks have no scales in the woods, which can be exceeded. The goal was then adjusted to 150,000lbs. It was subsequently learned that oil companies can get permission to move refinery equipment up to 230,000lbs on frozen roads, so the goal was increased to 250,000lbs.

1.7.2: Hardness

The scale to measure the hardness of materials is called the Mohs hardness scale. It refers to the resistance of a material to being scratched. It lists materials from the softest to the hardest e.g., on a 1 to 10 scale, with talc earning a 1 and diamond, (the hardest common material) being 10. Asphalt has a hardness of 1.3, copper has a hardness of 3, iron and nickel have a hardness of 4, and steel falls between 4 and 4.5. As you move up the scale closer to diamond, you finally come to glass, which has a hardness of 5.5-6.0.

1.5.3: Strength

When the glass is tempered it becomes four to five times stronger than the non-tempered annealed glass listed on Mohs hardness scale. Tempering does not make the glass harder - just stronger. Bulletproof and bomb (blast) resistant glass is made with tempered glass. Solar Roadway Panels are manufactured in a similar manner. Tempered glass is less likely to experience a thermal break.

1.5.4: Texture/Traction

One of the many technical specs required for SR panels is for a glass surface textured to provide the same or greater traction than current asphalt roads offer (at a minimum) - even in the rain. A variety of textures were tested with a British Pendulum Skid Resistance Tester. Some did not provide enough traction, and one had such an aggressive texture it broke off a piece of the tester. The SR2 texture used was a midrange texture. The final testing results showed the texture was sufficient to stop a vehicle going 80mph (129kph) on a wet surface in the required distance. The test results apply to motorcycles and bicycles as well.

2. Literature Review

Solar panels having hexagonal section are now a part of electricity power generator. A solar panel can be placed on the road with sufficient reinforcement of glass and such materials that have the ability to resist the breakage of the panel and to pass the sunlight to generate power. The modern world is becoming more modern day by day and consuming power a lot. The solution is to take part in the renewable energy in such a way that would have low space of the installation. The solar panels earlier invented to lay on the road and generate electricity having lots of problems. These panels are durable but not suitable for its installation time on the special concrete pavement. But if some changes are made on the panels and the road, then it will be possible to lay the panels on the traditional road. Earlier panels are made with no lock system except the smart sensors. There are four holes

in the panel for water disposal. And the ground part is set on the raised steel bars. If we are not constructing that special pavement then we have to put some reinforcement which will help to stay the panels on the ground.
The literature review is divided into four parts, namely, using the Lock system, using of Rubber and gaskets, construction manual for side wall and general knowledge of about solar panel.

2.1 Using of lock System
Laying the solar panels on the rational road surface is not so easy. The panels will not be in the same place if we do not give them stability with reinforcement. The locking system is thus necessary to make stable the solar roadway panels. There are many unique designs available to lock one panel to another, but these panels need some special lock system which will support the panels side by side and supply the power also. Door locking system with hardware exhilaration is a part of this lock system. Both the locks are dependent on spring power. In the case of doors, the lock will be unlocked if we rotate the handle. But in the solar roadway panels, we can remove the handlebar. The handle bar is pushed down to lock the panels.

2.2 Using of Rubber and Gaskets
The laying of solar roadway panels on the traditional roads can be easily done with a lock system and a side wall, but the application of running vehicles and their vibration will damage the whole panel. And the comfortability of car driving will be affected. So a new way is to apply rubber in the panel side and beneath the panel. Use of any rubber will not be accepted because of durability, density, and compression stress. There are many types of synthetic rubber. The synthetic rubber of having proper durability, density, and compression stress must be used. Tire rubber is very suited for this work. Gaskets are used in the side joining walls of two solar panels. Bulletin of the *Transilvania* University of Braşov • Vol. 3 (52) - 2010 • Series I, Introduction to Fiber Science and Rubber Technology B. Rubber Technology, gives the proper choice of the rubber.

2.3 Construction manual for side wall and panel barriers
Construction of side wall helps the panel to stay on its position. This wall is constructed using concrete. The grade of the concrete is the grade of the drainage system. The drainage system is a part of the wall. The side wall and the drainage system are built together. The width of the sidewall is half of the drainage system. Panel barriers are also being used as per IS code.

2.4 General Knowledge about solar panel
Properties of a solar panel, the amount of power generation, the surface of the road, working procedure of panels, working mechanism of solar panel system supply of the water and electricity and all the information to introduce the solar panel are being collected from the maker of solar panel website, www.solarroadways.com. This website gives the introduction part of this project. But in the case of constructing solar roadway in the normal roadway, traditional roads must not exist in any matter. So some changes are made in the project construct the solar roadway on the present road surface. The behaviors of the panels are being collected from various website data online. Ground surface and bottom of the panels are being made of specially treated tempered glass and a specially combined mixture of waste materials respectively.

3. Working Principal
A solar roadway is a series of structurally-engineered solar panels that are driven on. The idea is to replace current petroleum-based asphalt roads, parking lots, and driveways with solar road panel that collect energy to be used by homes and businesses, and ultimately to be able to store excess energy in or alongside the solar roadways. Thus renewable energy replaces the need for the current fossil fuels used for the generation of electricity, which cut greenhouse gasses and helps in sustainable development. Parking lots, driveways and eventually highways are all target for the panel. If the entire united state interstate highway system were surfaced with solar roadway panels, it would produce more than three times the amount of electricity currently used nationwide Solar Panel has three layers.

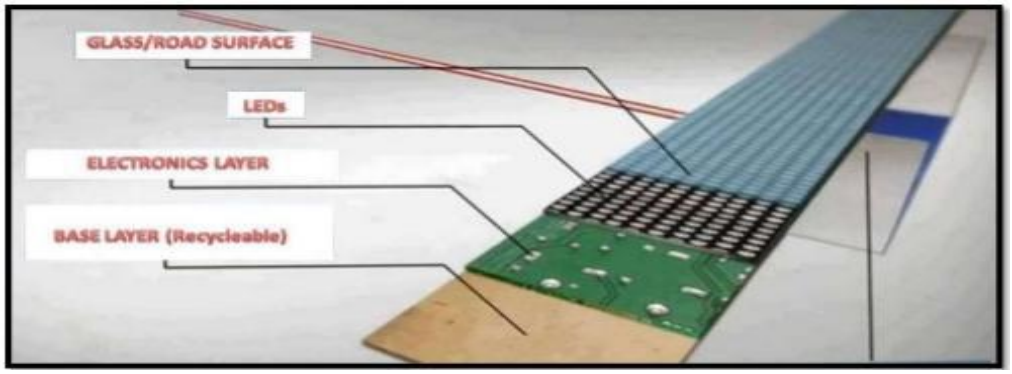
3.1 ROAD SURFACE LAYER
Translucent and high-strength, it is rough enough to provide sufficient traction, yet still passes sunlight through to the solar collector cells embedded within, along with LEDs and heating element.
This layer needs to be capable of handling today's heaviest loads under the worst of conditions and to be weather proof, to protect the electronic layer beneath it.

3.2 ELECTRONICS LAYER
It contains photovoltaic cells which absorb solar energy. It also contains a microprocessor board with support circuit for sensing loads on the surface and controlling a heating element with a view to reducing or eliminating

snow and ice removal as well as school and business closings due to inclement weather. The microprocessor controls lighting communication and monitoring etc.

3.3 BASE PLATELAYER

It needs to be weatherproof to protect the electronic layer above it. Distributes power and signals to and from the panel



3.4 Energy Storage

When it comes to the storage of the renewable energy produced by SR panels, a virtual grid system can be used with a specialized meter from the utility company that provides net metering. These meters spin backward when extra energy is produced. In turn, energy can be pulled back from the grid when needed to power the panel's LED lights and heating elements at night, or in a storm when the panels may not produce sufficient energy. Batteries were not selected for use in the SR2 parking lot since they tend not to be environmentally friendly and using the virtual grid spares one that purchase. One downside to this system is that there is no energy available during a power outage due to the fact that the micro-inverters disconnect when they don't sense energy on the existing power lines.

Those who want to have a storage system can incorporate most any kind of renewable energy storage for use along with their SR panels. Many potential customers say that they plan to use the new Tesla Power wall or other types of batteries. Any standard renewable energy storage device should work and could be placed in the Cable Corridor for easy access.

3.5 AC/DC

Solar cells produce DC energy. Homes and businesses currently use AC energy, so the DC solar energy is converted to AC energy by a DC-to-AC converter. Unfortunately, every time a conversion is made from DC to AC (or AC to DC), losses occur in the conversion. This means that some of the energy produced by solar cells gets lost when it's converted to AC for the home.

Many, if not most, of the electronics in our home, don't actually run on AC. They are plugged into an AC outlet, but then a circuit inside of the electronic device converts the AC to DC before using the power, creating another energy loss.

If solar energy became the primary energy source, then it would make sense to convert homes and businesses to DC. That way, the power produced by solar driveways, parking lots, roads, etc. wouldn't be wasted by being converted from DC to AC and then from AC back to DC again.

Since heavy duty DC motors are available, all common household utilities could be run on DC power. Appliance manufacturers would save money by eliminating the AC-to-DC converter circuitry that they would no longer need. That savings could be passed on to the consumers. Less power loss and more savings would be a win-win solution.

3.6 Greenhouse Gases and Climate Change

It is estimated that approximately half (different agencies provide different estimates, but the average is about 50-percent) of the greenhouse gasses that are causing climate change come from the burning of fossil fuels (primarily coal) to generate electricity. Solar Roadways, if widely adopted, therefore has the ability to eliminate half of the greenhouse gasses currently being produced. This would reduce pollution, make the air we breathe cleaner and safer, eliminate the ramifications of dependence on fossil fuels, and help slow climate change, which most scientists now agree is happening much faster than anticipated.

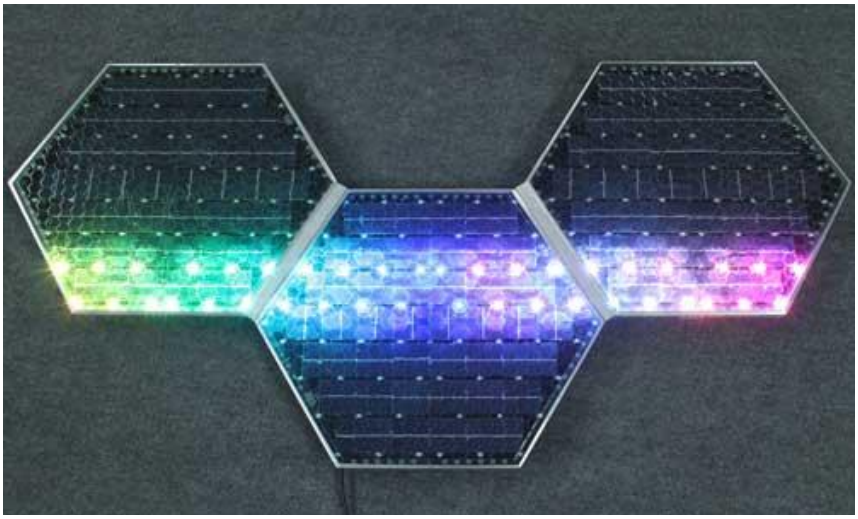
3.7 Repairs and Maintenance

SR is modular, so the repair will be much quicker and easier than our current maintenance system. Each panel assembly weighs less than 100lbs (45.36kg). A single operator could load a replacement panel and respond to the scene. The panel could be swapped out and reprogrammed in a few minutes. The damaged panel would then be returned to a repair center. In order to redirect traffic with minimal disruption, the operator could quickly redraw the LED road lines to create a detour, and just as quickly put them back to the default position when he or she is finished. Solar Roadways has a microprocessor located approximately every 2.5 feet. Since neighboring panels also communicate with one another, if a problem were to arise, the road would report it to a central control station.

3.8 LED Illumination

Solar Roadway panels have embedded LED lights to replace paint to make road lines and signage. In early development, it was quickly realized that creating panels with glass posed a problem: it wouldn't work to paint road lines over the solar cells, or on glass. But that realization was quickly followed by the solution: since SR panels are would be intelligent, it would be possible to make road lines and signage from embedded LED lights – eliminating the need for paint and the maintenance for keeping up with painted road line marking.

Using LEDs instead of paint opens up a whole new world of options. Road and parking lot lines, verbiage, and signage now become flexible and customizable. With embedded sensors, the intelligent road can use the LEDs to warn drivers of impending danger, such as a large rock in the road. Safety can also be enhanced by making the road lines more visible, especially in dark, foggy, or stormy conditions.



3.9 Traffic Management

The LED lights in Solar Roadway panels can be used in many different ways to create modern traffic management systems. The flexibility of having lights instead of paint creates options never before possible. Because Solar Roadways are intelligent; they can enhance the safety of citizens. This intelligence is expressed mostly through the LEDs. It's the way the panels communicate with drivers and pedestrians. Crosswalks will flash and tell drivers to slow down when a pedestrian is present. Highways will warn drivers of wildlife around a curve. Roads will create detours when there is an accident. LEDs can turn red when a fire truck (or EMS vehicle) is leaving its station on a call.

3.10 Visibility

Many people have poor vision at night, especially as they get older. LED lights are much easier to see than painted road lines on dark nights. It's expected that this Solar Roadways feature will reduce accident rates. Solar Roadside LED Road Studs™ in the UK have been shown to reduce nighttime accidents 70%, according to the company. Solar Roadways LED lights would provide even more visibility and would be cover much more area, which ought to reduce accidents more than that.

Road lines are also harder to see during weather events; such as rain or snow. Often in winter conditions, snow completely obscures road lines altogether, even with the best efforts of snow plow drivers. The LED lights combined with heating elements, which keep snow and ice off of the LED lights, will improve visibility in all weather conditions, enhancing the safety of travelers.

3.11 Elimination of Road Paint

The paint used for painting road lines is a short lived product. Oregon's DOT says that its goal is to repaint all of their road lines every year (although they apparently don't reach that goal). An article published by the Federal Highway Administration estimated that in the United States alone, approximately $2 billion is spent annually on pavement markings. Inconveniences result too, from traffic delays to complaints of paint getting on vehicles as they drive in areas that have been freshly painted. All such problems could be obsolete with SR panels.

3.12 Wildlife

The feature of Solar Roadway intelligent panels and LED warning system will offer never before seen protection for large wildlife. While the load sensors cannot detect tiny animals, such as a chipmunk running across the road, they will certainly detect large animals such as deer, and warn drivers, thus lowering wildlife caused collisions. Solar Roadways is anxious to help keep humans and animals safer by reducing this problem.

4. Designing Analysis of Cost Effective Solar Roadway

4.1Basic Criteria

Early planned Solar Roadways were such that they will be placed on the specially constructed concrete pavement. But the previously constructed pavement (Concrete or Asphalt Pavement) has to be withdrawn and then re-construct the needed special concrete pavement. The withdrawn of any pavement needs a huge amount of time and money. In such time the traffic operation will be affected for every highway with higher traffic intensity. If we consider the money needed for withdrawn and re-construction of specially designed pavement, we cannot provide such time or another route for a huge amount of highway. If we consider the time needed for a renewable energy producing smart highway, the time will be as much that it will be very costly. As the withdrawn time is higher and costly and the re-construction of special pavement is time dependent and more costly than an asphalt road, we cannot invest money and time for such a road. For the higher traffic intensity highways, the construction of the specially designed concrete pavement is not possible, although we consider the money investment because of huge time dependency.

So we have to construct such a cost effective Solar Highway or Roadway that deals with all those impossibilities.

The discussion of the new way to lay the solar panels on previously constructed pavements (concrete or asphalt pavements) is described analytically below.

4.2 Change in Design of Earlier Solar roadway Panel

4.2.1 Inter Locking system:

Previously discussed SR panels have no interlocking hardware system built in the panel. To construct solar roadway with the solar panel it needs to have special Concrete rigid pavement. But in this project, constructing the solar road in traditional roads or laying the SR panels on the road surface has a different problem without special pavement. The difficulties such that

1) The panel may be jumped out from the road due to the loading of heavy vehicles at the side of the panel. This means if one vehicle moves on the road and the wheel of the vehicle touches one end of the panel, then opposite end will tend to jump from the road surface.

2) The breaking of the vehicle may cause the solar panel to jump out and damage to the vehicle itself and the road panels. It can also distress the solar panel from each other. The previously made solar panels had four water removal holes/valves. In the new solar roadway panel, only one locking hole will be present.

So interlocking of the solar panel will create a bond between the panels so that the panels will remain in the same place.

3) Vibratory effect of vehicles will tend the solar panel to move out from each other and this moving of the panels may cause panels to break each other. The vibration of the vehicles also affects the equipment of the solar panel. So for giving a rigid condition to the panels, some changes are made to the solar panels. Such that Interlocking of panels and use of special materials to the bottom of the panels. In this project, the special material is Synthetic Rubber.

Information about modified solar panel described below.

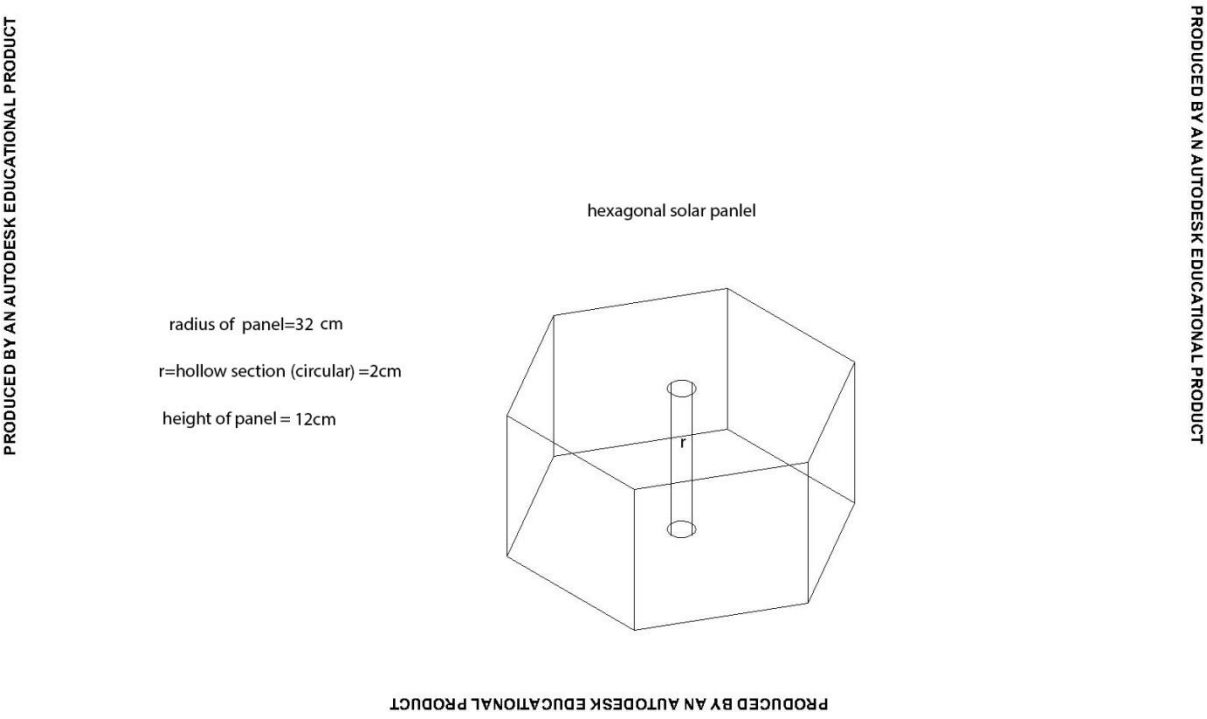
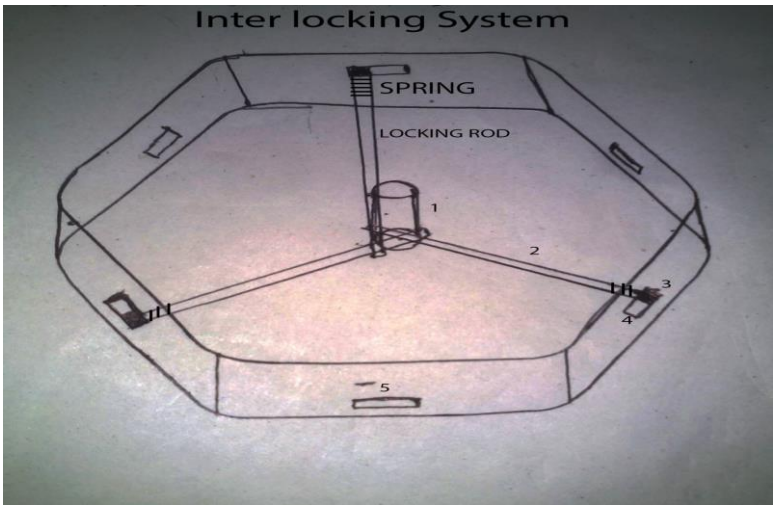


Fig- Hexagonal Solar Roadway Panel

The solar roadway panel section has six sides and bottom and the upper layer. The radius of the hexagonal panel is 32cm. and the height of the panel is 12cm. In the middle of the panel, there is a circular hollow section with a 2cm radius of which upper portion is open and the bottom is closed. The upper portion has patched section to be safe against water leakage. The lock system is provided on three sides one after one such that the middle side of two locking side does not have locking rod. But that arm has locking hole to get locked with the other panels.

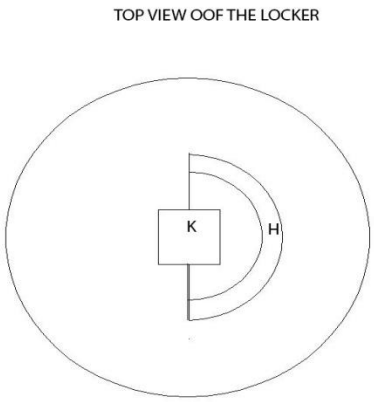


This locking system has three locking rods which are connected to the locking gear in the middle of the panel. The outside of the bar/rod has a spring. There is a hole beside the locking rod end. There is another hole between two locking rod in the arm of the panel.

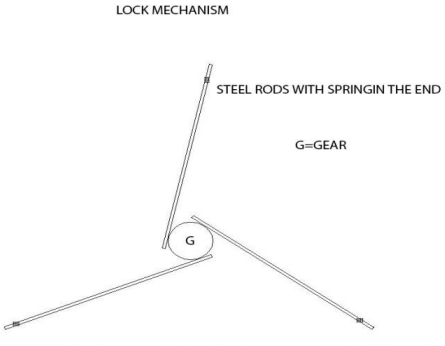
1. **Locking key barrel:** It is the switch of the panel which allows the panel to unlock from another panel. The locking rods always stay 2cm outside of the arm of the panel. When the locking key is rotated counter-clockwise, then the locking rods are pulled from the locking hole of joining the panel.

Fig- Locking Key Barrel

In the locking key, there is a barrel section of which down side is placed on a ball-bearing system, have a geared section on it in the height of locking rod. The locking rods are connected to the geared section. When the key is rotated, this geared section lets the locking rod to pull in. The upside of the key has a handle to pull the whole panel from ground. The following figure shows the upper side of the locking key. There is a key hole in the middle of the locker key.



2. **Locking rod:** locking rod is the locking element which joins two panels.



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3. The geared section holds the rod. This steel rod is made of corrosion less, stainless and high tensile steel. So, when vehicle pressure supposed on it, no cracking effect takes place on it. The diameter of these rods is approximately 1cm. approximately 2 cm of the rod stays always outside of the arm of the panel. Before placing the panel on the road, the locking rods are pulled to the center by rotating the locking key barrel counter clockwise.

4. **Locking holes:** Locking holes are the connector of two panels. Locking rods are pushed into the locking hole. These are rectangular sections. The locking hole inside the locking rod is of lesser area. And the locking hole between two locking rod is of the higher area. The holes beside the rod and the rods are fitted in such a way that the look of the mechanism of the whole lock takes counter clock direction. These holes are made of steel and protected with synthetic rubber around it after locking or joining of two panels.

4.2.2 Problem without interlocking system

The interlocking system provides rigidity to the panels. If this system is not provided to the solar roadway panels the overburden load of vehicles will try to make jump the panel from the road surface. Hence a bad effect on the vehicle movement will be found. In this case, the panels may be damaged and the driving of vehicles will not be smooth.

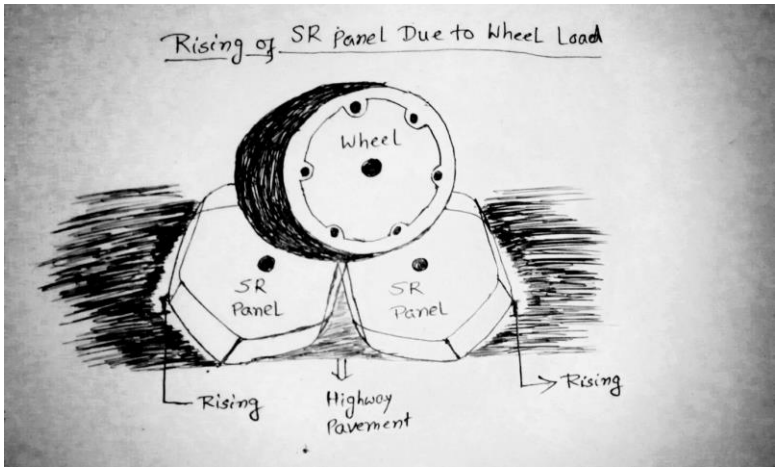


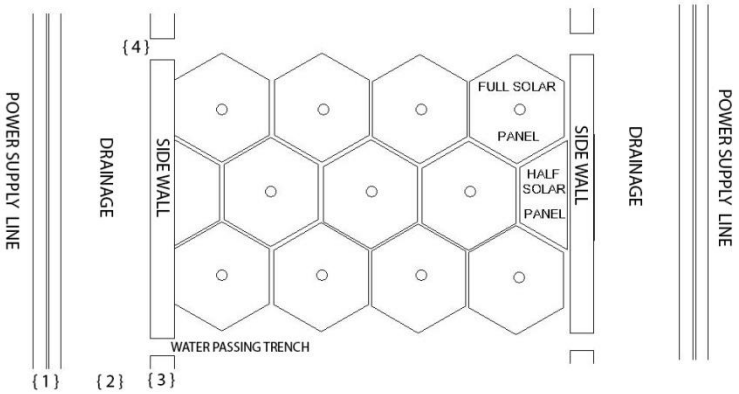
Fig- wheel load on the panel

It will also be shown that the panels will not be in the same place. So the interlocking system must be provided on solar roadway panels to give a smoother and safer transport of vehicles.

4.3 Solar roadway panel layout with all road components

Solar roadway panels are being lay on the road surface such that on the asphalt surface. These panels are placed on the road in the form of the below figure.

Solar roadway layout with solar panels



4.3.1 Solar roadway panels on asphalt road

Solar roadway panel layout looks like bee house. There are two types of panels. Namely, full panels and half panels are present. Half panels are put between two full panels beside the side wall. And in the other portion, there are full panels put. The panels are put in such a way that the radius of the panel is higher in parallel to the side wall and lower in the tangent direction of the side wall.

4.3.2 Sidewall

The side wall is provided on the road to stop the deflection of the panel insides.
There are locking holes present in the side wall.

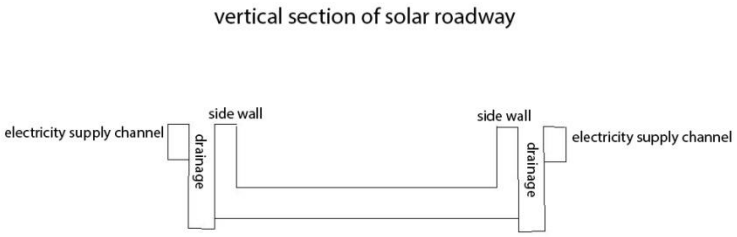


Fig- vertical section of solar roadway

Vertical defines that the side wall is raised up from the road surface. But the height of the side wall is just same as the height of the solar roadway panel. It is 14cm to 14.5 cm in height from the road surface. And the width of the side wall is about 20cm. This side wall is made of concrete with high reinforcement.

4.3.3 Drainage system

The drainage system is same as other roads. But it has a width of 75cm to 100cm.During rain, rain water will pass over the solar panel surface. But leakage occurs between two panels. So the little amount of water will pass through the panels. So this rain water will have to be removed to the drain. The inclined road makes the water to go to the side wall. But if, the side wall has no water disposal holes or trench then that water will stay there until it gets dried. So there is trench applied in the side wall and the side wall is not thus continuous.

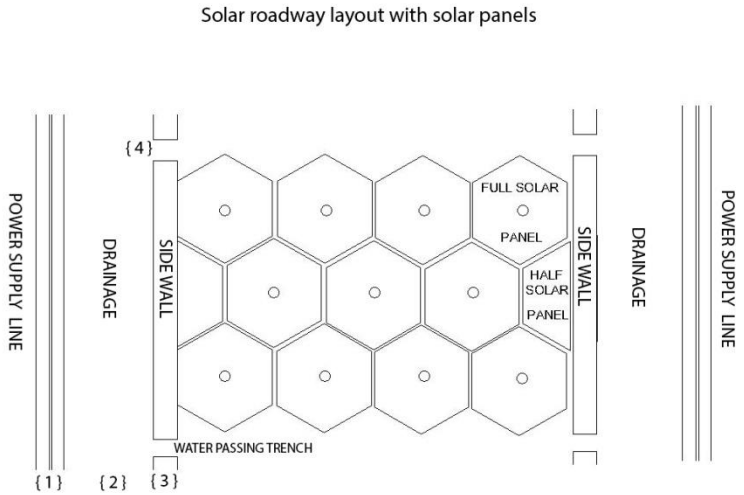


Fig- water passing trench

In the figure above, there is provided water passing trench marked as {4}.The size of the trench is not greater than 14cm*10cm.

4.4 Use of rubber to counteract the effect of vibration

When a vehicle moves on the solar panel surface, the vehicle itself produces lots of vibration. That vibration will damage the whole panel system. To counteract the vibration effect, the synthetic rubber material is to be used. The actual and affecting rubber should be claimed from the market or produced by the self factory. Rubber is very useful to soak the vibration effect. There are various types of rubber in the market but few of them can be taken as the solar road vibration counter actor. The hardness of the rubber should be medium and the tensile strength of the rubber should be greater. The width of the rubber may be taken as a maximum of 2.5 cm. and the rubber size must be same as a solar roadway panel size. The rubber is passed with high strength glue under the panel.

The bottom surface of the rubber is not smooth. It is same looking as the surface of the panel's glass. It is required to include the textured pattern on the rubber so that it can stay in the same place due to its friction with the asphalt. Friction coefficient between asphalt and rubber is higher.
Coefficient between rubber and asphalt is between 0.5to 0.8. So the rubber is stable on the asphalt surface. The weight of a solar panel is more than 40 kg. So, in the high speed of the vehicle is unable to force the panel to slide or skid.

4.4.1 Rubber between two solar panels
Bottom of a solar roadway panel is covered with thick rubber to counteract the effect of the vibration of vehicular movement. But the portion of the joint of two solar roadway panels is unsafe from collusion with each other during vehicular movement. In this manner, panels may be damaged. So to make the panels safe from their collusion with each other, thin layer of rubber is to be provided. The thickness is 50mm.

4.5 Panel barriers
What will be happened if we construct continuous solar panel roadway is the horizontal displacement of panels in the direction of the horizontal thrust of vehicles. So the solar panels must not be continuous in order to get strength against the horizontal thrust of the vehicles.
In order to counteract the horizontal thrust, a barrier is provided after every 100meter to 150 meters. The width of the barrier is about 20cm. These panel barriers are made of reinforced concrete. The height of the barriers is same as the solar panels with the bottom rubber layer, 14cm.

4.6 Pre-work in the asphalt road before placing the solar panel
In order to place the solar roadway on the asphalt road, the road should be smooth, clean and dry. The solar panel cannot be placed on the road having holes or raised sections and other rough forms. If we place the panels in the rugged or rough road surface then the panels will easily be broken in vehicular movement effect. And the movement will not be smoother.
So the road surface must be treated to make it smoother to place the solar roadway panels.

5. CONCLUSIONS

5.1 Summary
This project is on the basis of solar power electricity generation during day time. It produces 4241 billion kilowatt-hours of electricity in an area of 8794 square miles which is the transportation highways. The panels used on the roads are smart enough to make it perfect for the well known smart cities. The locking system to be used on the panels, drainage, and carriageway strength is more stable. The power supply is done with the ground channel system. Repairs and maintenance cost is low. Smart traffic management is with led illumination. Road paint system is eliminated in this solar roadway system. The use of the interlocking system in the panels helps to place it on the road without having special construction. Side walls, panel barriers are provided to counteract the thrust produced by vehicles. To make it safe against vibration, rubber materials are provided at the bottom of panels and also on the sides.

5.2 Concluding Remarks
A futuristic project always deals with various impossibilities. This project is now in research level. Only the founder of the solar roadway, have made his own parking lot with the solar roadway panels and the country Netherland has also placed a solar roadway in a park road. The beginning of the futuristic roadway will make our dreams come true to become smarter, safer, faster, easier and poisonless. Villagers will get sufficient power supply to make their life easier. If we stay in the Mars, then Solar Roadway will take a very important role in the power supply to the electric components.

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