Chapter 27

Landscape Engineering, Protecting Soil, and Runoff Storm Water

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Additional information is available at the end of the chapter

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1. Introduction

Landscape engineering thinks about the application of mathematics and science to the creation of convenient outdoor living areas. These outdoor living areas are a consequence of the design and the construction process made feasible by landscape architects through landscape contractors. Beside landscape engineer's interested in containing site grading and drainage, earthwork calculations, and watersheds [1,12,13].

Landscape engineers employ engineering knowledge when designing and building spaces. They demand to know how to interpret contour maps which shows elevations and surface configuration by means of contour line sand and also consider how to interpret 2-D images, compute angles and grading requirements for pavements, parking lots, bridges, roads and other structures. Beside they understand the amount of fill needed for specific areas and figure out how water runoff and flow should affect their designs.

Developing and improving for landscape engineering [1,3,13,14]

1. Stormwater management: building up bioswales, landscape materials used to gather and install runoff, rain gardens and porous asphalt.
2. Mitigation of the urban heat island effect: diminishing the quantity of paved surfaces, building up green roofs and green walls, and using building materials with low reflectivity.
3. Wildlife habitat: protecting habitat and building up green roofs and rain gardens.
4. Social spaces: areas for walking, biking, gathering and eating.
5. Transportation: growth expanding pedestrian accessibility, limiting vehicle speeds and encouraging the use of public transportation.

All above are using for the mixing plastic with asphalt on the pavement for the above reasons. One of them we are using porous plastic asphalt on the pavement for diminishing the sounds of road, and protecting the soil, and making runoff out the structure.

Porous plastic pavement which is a permeable pavement surface permits the action of storm water in order to infiltrate directly into the soil. It usually constructs with an underlying stone supply that temporarily stocks surface runoff before infiltrating into the subsoil. It takes the place of traditional pavement. There are various types of porous surfaces, including porous asphalt, permeable concrete and even grass or permeable pavers.

Porous plastic asphalt pavements suggest an alternative technology for stormwater management. It is varied from classical asphalt pavement designs so that the structure enables fluids to come frankly through it, decreasing or monitoring the amount of run-off from the surrounding area. By permitting precipitation and run-off to running out the structure, this pavement kind functions as an additional stormwater management technique. The mainly benefits of porous plastic asphalt pavements should contain both environmental and safety benefits including improved stormwater management, improved skid resistance, decreasing of spray to drivers and pedestrians, as well as a potential for noise decreasing. Porous plastic asphalt is applicable to many uses, including parking lots, driveways, sidewalks, bike paths, playgrounds and recreational courts. In addition, with proper maintenance, including regular vacuuming or pressure washing of the pavement surface to prevent clogging by sediments, porous asphalt can have a minimum service life of twenty years [15,16,17,18].

Bitumen is a valuable binder for road construction. Different grades of bitumen which is 30/40, 60/70 and 80/100 are available on the basis of their penetration values. The steady growth in high traffic intensity in terms of commercial vehicles, and the important variation in daily and weather temperature demand developed road characteristics.

Nowadays the waste plastics are to exist tremendous, as the plastic elements have been piece of daily life for using. They either blended with Municipal Solid Waste and/or dispose of landfill. If not recycled, their present disposal is either by land filling that the method has certain impact on the environment. Because of that an alternate use for the waste plastics is also the needed.

Thinner polythene carry bags are most adequately disposed of wastes, which do not draw attention the attending rag pickers to accumulate for forward recycling, for lesser value. These polythene bags are simply suitable with bitumen at specified conditions. The waste polymer bitumen mix may be prepared and a study of the properties can throw more light on their use for road laying.

Permeable pavements have been sufficient in behalf of environmental problems and corroborating sustainable green construction procedures. They are planned to support surfaces for parking lots and pedestrian roads that will permit some of the precipitation to filter into the ground, decreasing the bulk of stormwater runoff and revitalizing groundwater [15,16,17]. Permeable porous asphalt and concrete are the most ordinarily used elements in permeable pavements. Permeable asphalt uses practically the similar elements as conventional asphalt, order than the percent range of plastic added, and the size of the aggregate is used to stay thin, permitting for minimum particle packing [16,17]. Permeable asphalt and concrete has been successfully implemented for road, retaining walls, streets, driveways, sidewalks, parking lots, and slope protection for the past 30 years in many countries, including the United States [17]. None of any researchers, to the authors' knowledge, have inquired for mixing permeable plastic asphalt so far that implement plastic waste as a binder bonder for permeable pavements. This study presents an alternative sustainable technology, familiar as permeable plastic asphalt, which should be implemented for permeable pavements. Permeable plastic asphalt material is produced from plastic waste, porous aggregates, and asphalt. The research evaluated the mechanical and hydraulic characteristics of permeable plastic asphalt.

An asphaltic paving material involves 4%, 5% and 6% percent, of granular recycled plastic (LDPE with 1%, 3%, and 6%), which supplements the porous aggregate component (aggregate size of 3/8, 4, 8, 16) of the mixture. The material produces a structurally superior paving material and longer lived roadbed. The plastic can contain any and all residual classes of recyclable plastic. The material produces roadbeds of higher strength with less total asphalt thickness and having greater water permeability, and is most useful for all layers below the surface layer. A process of shredding or mechanically granulating preferably forms the paving product.

A porous plastic asphalt pavement has benefit for using road users and road side environments such as decreasing road noise, developing drainage function, and driving security situation. Furthermore, the worth of porous asphalt is to support skid resistance, particularly in the wet weather, that is distinctly better than that of dense traditional asphalt [19].

Conventional asphalt was not usually acceptable in the high temperature, humid, and traffic. As a result that some of issues were occurred like the pores were clogged, strength of drainage, rutting and scattering came off by traffic loading [20]. Large percentage of air voids of the mixture is adopted in order to maintain the drainage function. Nevertheless, in the way that the proportions of air void grow, strength feature of the mixture diminish. This is the main theorem of asphalt mixture. For solving this, landscape engineers think about the plastic for design and planning as binder.

The aim of this research is to assess strength, which means the performances of porous asphalt mixtures, for testing Resilient Modulus to find Indirect Tensile Strength (ITS). Furthermore, it measures the durability of porous asphalt mixture using Marshall Immersion test.

It is the aim of this chapter (book) to outline the elementary essential parts fundamentals associate with the design, plan, and construct of pavements and to mix with plastic techniques that will allow a Landscape Engineer to plan and design a pavement to suit a variety of situations. After experiments next books chapters will be considered to help environment and nature same as protect soil and recycling. Next study will keep going to research the better experiments about permeable surfaces for using different plastic materials. As a result it gains economic, environmental, and practical design and plan for Landscape Engineering.

1.1. Landscape engineering

Landscape Engineering defined that is the art of developing land for people use and entertainment in such a manner as to obtain the utmost utility including with the utmost of beauty. It is a mistake to take into consideration the subject as implicated mainly with planting trees or to visualize its main function to be the supply of some decorative camouflage for some unsightly utility. Conversely, it has to be comprehended as a most important fundamental to life, and all art, which no utility would be necessary camouflage, and that every kind of artistic proceedings, instead of being without deep, has to be natural structural. Landscape engineering verifies the fundamental utilities, not as a necessary bad, but as necessarily well. In lieu of these utilities existing in the way of the objects, which the landscape engineer is succeed in doing, they turn out a most sufficient part of her/his own initiative. Apparently, once this point of view is admitted the Landscape Engineer and the others are definitely suiting for the same thing. Landscape Engineering impresses the main ideas, concepts, and techniques that cope with the functional, visual, and ecological perspectives of grading and landform cultivation. Landscape Engineering points out introduction to the processes, principles, and techniques of site engineering [1,3,13,21,22,23].

Students who pursue to study their career in Landscape Engineering programs learn about Landscape Design and Planning, Transportation Plan, Structural Landscape Design, Urban Planning, Site Planning, Ecological Design, Environmental Design, and Horticulture. Essential aims of all of subjects in Landscape Engineering pay attention to cover sustainability, and eco-friendly landscaping processes. They usually not only study with their specific area of studies like sustainable urbanism, environmental hazard management, historic preservation, ecological design but also focus in land development along with construction management, or a compound of land development and architecture [2,14].

Landscape engineer is that construction is the first step after designing and planning. Landscape engineer have to be continually consider to reach suitable adjustments between the operating cost, the construction cost, and the maintenance cost. For only during the construction period can the required savings be influenced at a minimum of expense. Landscape engineer think about completed without mention of subgrade conditions or specifications on material and method of placing while designing and planning pavement, parking lot, etc. Drains are often paid attention as releases for storm water during the catch basins although the drain is laid to accumulate the soil. With new experiment in planning is the topographical survey, usually worked out with care and precision during considers drain and protects soil.

Landscape engineer has to keep in mind when planning the pavement that it is a business proposition as well as a picture designing and planning. That the Landscape planned with an eye to operation and maintenance cost must in time, have the better financial situation to protect appearance. Meanwhile design and plans are begun; we have to never forget that budget is a factor in maintenance, whether the project is considered on the constant care principle. The complete design of the pavement is that while every element of pavement construction must be considered from the point of view of beauty and aesthetic value, the weight of construction, operation and maintenance must be found and recognized at the time of beginning [3,22].

A Landscape Engineer conducts and takes advantage of the strengths of nature for the benefit and satisfaction of man. For instance, if you were designing and planning a new landscape for your property and wanted to direct the winds to preserve your amusing areas, a Landscape Engineer would help you make a determination which trees to get and where to plant them; thus, the wind could avoid your patio or courtyard. Landscape engineering involves with the application of mathematics and science to the constitution of practical outdoor living areas. These areas are a conclusion of the design and the construction process made possible by landscape architects, along with landscape contractors. Other main contemplates of landscape engineer's include drainage and site grading, watersheds and earthwork calculations. It is the Landscape engineer's act to vigorously interest in the design of the landscape, hence, to significantly supervise the creation of the landscape design. Landscape engineering exemplifies the traditional engineering elements of planning, operation, management, design and construction, and assessment. Before planning and designing, Landscape engineer should consider three main areas that focus on [4,5,24]:

1. Landscape plan and design that Landscape Engineers interest planning the individual landforms so that they go along with the objectives arrange in the termination design phase. It is necessity that the Landscape engineer confers with the rest of the architectural team for carrying out a sufficient visual result once the construction process is finished.
2. Termination design and plan that it implies setting targets as well as supporting the Landscape design of the project at hand. Landscape engineers who works very closely with the contractors and sub-contractors does for working with Landscape designers as well as the owner of a home or property for deciding what the desired look is considered together and the essential steps to be taken in order to success it.
3. Functioning assessment that the reason of performance evolution of the Landscape engineer results in estimating liability and financial assurance of the landscape design and plan project. Thus, performance evaluation is vital to both the closure planning progress and performance evaluation.

1.2. Soil protection

As we preserve air and water, which we use for breathing and drink, the soil is very important as well. The quality of soil takes care of ecosystems. Soil quality, which would be linked to water quality, is a measure of soil productivity. As a determination soil quality which particularly, the bulk of soil to operate within ecosystem borders to endure keep up environmental quality, biological productivity, and support plant and animal health [25,26,27].

Soil structure and water infiltration is very important for soil quality as well as aim attention at characteristics like organic matter content overall soil biological activity, nutrient availability, and total organic matter levels [25,27]. Soil can be protected from erosion, landslide, and compaction by mixing plastic materials. Soil conveys very easy underground by water. Soil, which is ancient, rock broken into sand, silt and clay is the recycled and continuously transforming.

The one of ways for protect and sustainably improve of soils is mixed cover pavement with plastic materials for prevent erosions of soil. Soil tests should be recommended for mixing with compaction plastic. It is evaluated compliance with hydrologic characteristics like drainage from plastic compaction.

1.3. Stormwater runoff

Stormwater runoff comes off while precipitations from rain or snowmelt infiltrate the ground. Impermeable surfaces like pavement, driveways, parking lots, sidewalks, and streets restrain stormwater runoff from naturally permeate into the ground.

For understanding the impact of stormwater runoff firstly need to consider how important water cycles through the urban environment. The bulks of precipitation infiltrate forests flows slowly underground, are infiltrated in by natural progress, and eventually arrive at lakes, streams while is being its natural. When we design and plan to compress the land with roads, parking lots, and buildings, the natural progress of water infiltrate in the earth is diminished. The existing grasslands and forests are put in place of concrete, roofs, and asphalt that do not permit rain to infiltrate the earth. Rather than, the precipitations soak through as faster as directly into streams, storm drains, and all without the profit of filtration. Designing, planning and constructing with mixing plastic material help to infiltrate water on the driveway, parking lots, pavement in place of concrete or asphalt. Thus, they permit stormwater to quickly drain into the ground [28,29,30].

Stormwater is water that directly results from a rainfall event is not absorbed into soil and rapidly flows downstream, increasing the level of waterways. The flow of water results from precipitation and that occurs immediately following rainfall or as a result of snowmelt. Stormwater is the portion of rainfall that does not infiltrate into the soil. Rainwater and snowmelt that runs off impermeable surfaces rather than infiltrate into the soil through a drainage system of underground pipes, stormwater carries nutrients, fine soils, plant debris, drippings from vehicles, and other substances from the drainage basin most of lakes, ponds, and wetlands are connected to the stormwater system. Water collected in a system of pipes which drain roads and industrial or trade premises Stormwater may contain contaminants present on drained surfaces.

Stormwater is concerning about two issues that are the volume and timing of runoff water and prospective polluting. Stormwater is needed to flood control and water supplies. Also stormwater lead to be water pollution for conveying the water. As a stromwater, watermanagement on the pavements should probably do urban environments self-sustaining in terms of water. Stormwater is pollution because impermeable surfaces like parking lots, roads, buildings, compacted soil do not enable rain to drain into the ground. More runoff is constituted than in the unprogressive condition. Thus, it should consume waterways like flooding after stormwater collection system is overwhelmed by the additional flow. So the water is out of watershed way through little drainage the soil, the storm event [31,32].

Stormwater is a problem so that it could collect chemicals waste, mud, dirt, and other pollutants and infiltrate in the storm sewer system or directly to a river, lake, coastal water, stream, or wetland. Anything, which inserts a storm sewer system, is released untilled into the waterbodies we run for fishing, swimming, and supplying drinking water.

The results of pollution of stormwater runoff could have many unfavorable effects on animals, plants, people, and fish. Sediment that could blur the water and make it complicated or unimaginable for aquatic plants to grown could demolish aquatic habitats. The pollution of stormwater usually influences drinking water sources, which could transform to imitate human health and grow drinking water treatment costs.

The solution of pollution of stormwater that is permeable pavement consists of mixing plastic. Traditional concrete and asphalt don't tolerate water to infiltrate into the ground. Rather than these surfaces depend on storm drains to switch unwanted water, Permeable pavement systems permit rain and snowmelt to saturate with, diminishing stormwater runoff [28,32]. Stormwater runoff is without filtered water that arrives at oceans, streams, and lakes by means of streaming on impermeable surfaces that contain driveways, parking lots, roads, and roofs.

1.4. Correlation between impermeable pavement and permeable runoff

Impermeable pavement in a watershed occurs in growth permeable runoff. The barely 10 percent impermeable pavement in a watershed would occur in stream decline.

Stormwater is pollution so that impermeable surfaces like parking lots, compacted soil, roads, buildings, do not permit rain to flows off from the land in the streams, further runoff is caused to be than in the immature condition [28,31].

This further runoff would spoil streams and rivers as well as bring about flooding after the stormwater system is overflow by the extra flow so that the water is reveled out of the watershed through the storm event, barely drains the soil, fills groundwater, or stocks stream baseflow in dry weather. Contaminant inserting surface waters during rain that is lead to contaminate runoff. Daily people activities appear in sediment of pollutants on parking lots, farm fields, driveways, roads, lawns, roofs. As soon as precipitation begins, water flow off and eventually makes its way to a lake, ocean, and river.

A traditional city block creates more than five times more runoff than the forest because of impermeable pavement. The waste of penetration from city may come out with depth groundwater changes [28,31,32].

The present drainage systems, which accumulate runoff from impermeable surfaces like roads, parking lots, roofs insure that water is effectively transported to ways of water during pipes. As a matter affects little storms water occur in growth ways of water flows. Stomwater lead to some of issue that shows below.

1. Impermeable Pavement
2. Roads, sidewalks, rooftops, overly compacted soils
3. Do not allow for natural infiltration of stormwater
4. Increase temperatures (Heat Island Effect)
5. Degradation of water quality and natural habitats
6. Flooding, erosion and may reduce groundwater levels

1.5. Class of plastic for using contemporarily

The simplest way for a user to label the class of plastic used in a product is to recognize the resin identification code, which is familiar with the material container code as well, is generally plotted, shaped or symbolized in or close to the middle of the bottom of the product. In accordance with the society of the plastics industry (SPI) resin identification code (or material code) is to systematize mutual plastic resins and their characteristics.

The identification of plastics made known in 1988 by The Society of the Plastics Industry Trade Association (SPI) that provides to build the companies for easy recycles make collect the consumer plastics during the common pathways for coming together recyclable stuffs from household waste. It is based on willing for plastic manufacturers, however, it has evolved into comparatively standard on plastic products sold in the U.S. and internationally. For example, the identification of plastics is in service and is affirmed by the Canadian Plastics Industry Association (CPIA) in Canada. It supports specifics on the identification by mean of its Environment, health and safety strategic unit and its Environment and Plastics Industry Council (EPIC) [7,33,34].

The aim of the identification provides to make it simpler for recycling to plastics. Furthermore, it determines consumers with an easy, handy method for identifying the class of plastic resin used to create a specific product. In conformity with SPI identifications, the number is intentionally located in an unnoticeable place on the product so that the company purpose is not to affect the consumer's buying determination, barely to assist the progress of recycling of the product.

According to SPI, there are seven different classes of plastics. Showing Figure 1, the identification numbers imprint on the bottom of plastic products that is a number inside of triangle represents to mean their identifications for recycling. Have you ever been curious about what the numbers inside the little recycling symbol mean on all of the plastic packaging and plastic products which we consume for using?

According to SPI the identification in 1988 reciprocates to the consider revising of the plenty recyclers side to side the countries. Here each class of plastics number and definition [7].

1. PETE, PET (Polyethylene Terephthalate) is clarity, strength or toughness, barrier to gas and moisture, resistance to heat. It uses for consuming plastic soft drink and water bottles, beer bottles, mouthwash bottles, peanut butter and salad dressing containers, oven able film, oven able pre-prepared food trays.

Figure 1. Samples of identification on the bottom of plastic water bottles

2. HDPE (High Density Polyethylene) is stiffness, strength or toughness, resistance to chemicals and moisture, permeability to gas, ease of processing, and ease of forming. It uses to make plenty classes of bottles. The bottles are clear, have good limit qualities and stiffness, and are quite appropriated to packaging products with a short shelf life like milk so that HDPE has good chemical resistance; it is used for packaging many household and industrial chemicals such as detergents and bleach. It uses milk, water, juice, cosmetic, shampoo, dish and laundry detergent bottles; trash and retail bags, yogurt and margarine tubs, cereal box liners.
3. V, PVC (Vinyl, Polyvinyl Chloride) is versatility, ease of blending, strength or toughness, resistance to grease or oil, resistance to chemicals, clarity. It has well chemical resistance, weather ability, flow typical features and constant electrical qualities. Products made from Vinyl can be both flexible and rigid. It uses toys, clear food and non-food packaging, shampoo bottles, medical tubing, wire and cable insulation, film and sheet; construction products such as pipes, fittings, siding, flooring, carpet backing, window frames.
4. LDPE (Low-Density Polyethylene) is ease of processing, barrier to moisture, strength or toughness, flexibility, ease of sealing. It is used efficaciously in film uses because of its flexibility toughness, and approximate transparency, making it familiar for use in uses that heat sealing is essential. Furthermore, LDPE uses to procedure some flexible lids and bottles as well as in wire and cable uses. It uses squeezable bottles (honey, mustard), coatings for paper milk cartons and hot and cold beverage cups, container lids, toys, dry cleaning, bread, and frozen food bags.
5. PP (Polypropylene) is strength or toughness, resistance to chemicals, resistance to heat, barrier to moisture, versatility, and resistance to grease or oil. It has good chemical resistance, is strong, and has a high melting point making it well for hot-fill liquids. This resin is brought to light in rigid and flexible packaging, fibers, and large pattern parts for automotive and consumer products. It uses containers for yogurt, margarine, takeout meals and deli foods, medicine bottles, bottle caps and bottles for ketchup. Furthermore, for packaging, its plenty of uses are in fibers, appliances and consumer products, containing strong applications like automotive and carpeting.

6. PS (Polystyrene) is versatility, insulation, and clarity, easily foamed as known "styrofoam". It is clear, hard and brittle. Also, it has an approximately low melting point. General uses contain protective packaging, food packaging, bottles, and food containers. It is usually connected with rubber to make high impact polystyrene (HIPS) that is used for packaging and constant uses necessity stiffness. It uses compact disc cases, food- service applications, grocery store meat trays, egg cartons, aspirin bottles, cups, plates, and cutlery.
7. Other is dependent on resin or combination of resins. Use of this number represents which a package is made with a plastic other than the six listed above, or is made of more than one plastic and used in a multi-layer combination. It uses usually shows the exits of polycarbonate which a hard, clear plastic used to make baby bottles, water pitchers, nalgene brand water bottles, three and five-gallon reusable water bottles, food containers, some citrus juice and ketchup bottles, compact discs, cell phones, automobile parts, computers, three and five-gallon reusable water bottles, some citrus juice and catsup bottles, oven-baking bags, barrier layers and custom packaging.

2. Development of design

2.1. Design factors

The area of pavement design is vigorous in which ideas are steadily changing as new data evolve into achievable. For mixing plastic pavement that are many majority of design and plan applicable, since alternatives relating to sustainability, suitability of designs and plans alter from area to area. Especially, supplies that are applicable for construction and foundation of pavements have a higher impress on design and plan. There are, nevertheless, fundamentals of design that are mutual to all problems irrespective of other uncontrollable situation [35,36,37,38,39].

The plan and design of pavement embrace with a work of soils and paving materials, their action under load, and the plan and design of pavement to convey which load under all hydraulic and weather situations. All pavements obtain their eventual support from the underlying subgrade. As a result, a comprehension of elementary plastic materials, pavement design and soil mechanics is necessary. Landscape Engineers are familiar that efficiency of pavement that are connected to a large volume upon the types of plastic, soils over that the pavement is designed and constructed, therefore, in relationships pavement efficiency between subgrade types are built. On the whole, the experiments of mixing plastic pavement demonstrated that pavement designed and constructed over plastic displayed higher degrees of distress than those designed and implemented over traditional pavement. Frost process and unfavorable drainage situations were observed early as two of the primary reasons of pavement lapse.

However, many landscape engineers are made use of standard cross components for most pavements. It means that a road, even though it crossed several mixing plastic and soil types, was designed and implemented using a constant thickness. The foreseeing was usually confirmed on the rest of economics. Beginning of 1980s, people recognized that the traditional pavement affects the environment and nature. All of thriving technological elements such as cars, bike for becoming a simple life causes to influence the pavements lapse [40,41,42,43].

2.2. Conventional pavements

AASHTO have been in charge for various tests, which roads designed and implemented in United States as well as some of state highway departments have implemented test pavements for the aim of assessment the influence of load and elements on pavement design.

There is a small suspicion that the outcomes of test results have had extreme effect on current design ideas. Furthermore, efficiency of example pavements in service has had important effect on design. This is not shocking, if one thinks that it is hard to do if not unreasonable to judge entirely design ideas in the laboratory. In addition, it has been familiar with for quite a while that reader belief in the final analysis imposes the competency in some of the design.

2.3. Definition pavement types

Basically, with regard to history of pavements have been classified two main types which are flexible and rigid. Flexible pavements comprise asphalt. Nowadays flexible pavement is very important with mixing plastic so that makes permeable areas.

Plan, design, and construction of permeable pavements have altered rather importantly in the last decades. On account of the current traditional plan, design, and construction pavements come up severe higher traffic levels, wheel loads, pavement lapse. A growth use of balanced is base and subbase. Balancers such as asphalt, plastic are repeatedly used to grow the structural strength of the pavement by growth rigorously. Because of the reason an extremely concentrated effort was made in the last several years to develop a more fundamentally based design analysis for asphalt.

2.4. Permeable plastic asphalt

Some of researchers assessed the impact of moisture susceptibility on porous asphalt samples [44]. Samples were based on wet and dry conditions and then tested for indirect tensile strength test (ITS). Results showed that ITS decreased noticeably when the sample was immersed in water.

2.5. Purpose of plastic asphalt

The aims of the study are need to do those. First of all; Disposal of waste plastic is a major problem, non-biodegradable, burning of these waste plastic bags causes environmental pollution. Secondly need is it mainly consists of low-density polyethylene, and to find its utility in bituminous mixes for road construction. Thirdly, Laboratory performance studies were conducted on bituminous mixes. Laboratory studies proved that waste plastic enhances the property of the mix, and improvement in properties of bituminous mix provides the solution for disposal in a useful way.

Waste plastics like polythene carry bags, etc. on heating usually at approximately 160°C. According to thermo gravimetric results has demonstrated that gas evolution isn't found during the temperature rank of 130 to 180°C. Furthermore the mellowed plastics have a binding feature. Therefore, the melted plastics can be implemented as a binder that they should be blended with binder like bitumen to improve their binding feature. As a result it should be a good modifier for the bitumen, implemented for road construction.

2.6. Function of the mix plastic asphalt

The growth of plastic city wastes has affected to wide and creative technologies that incorporate recycled plastics in miscellaneous uses. Scientists and Departments of Transportation have been interested in different researches regarding to the feasibility, economic and ecological impact and the complete efficiency of recycled plastic in connected landscape engineering projects. For instance, recycled thermoplastics like PET, HDPE, and LDPE, have been implemented in porous asphalt mixtures to put in place of aggregates with specified diameters [45,46,47,48,49,50]. Conclusion from these researches demonstrated improvement in strength, durability, and fatigue life. Nevertheless, the scale of improvement is a capacity of the plastic types and amount. The rest of researchers implemented recycled plastic strips to mechanically stabilize and aggregates by mixing plastic shreds with aggregates to compaction to defeat inadequacies in grading and diminishing the plasticity index [51,52,53]. The scale of enhancement was affected by many factors like the class and volume of shreds, and aggregate classes. Furthermore, creative and innovative study has cause to the development of new mixed elements using recycled plastic waste for miscellaneous uses. The mixed is produced by heating and blending the absorption elements, recycled plastic, which flakes, shared, or unprocessed, granulates and by products to a highlighted temperature. The heated combination is then compacted into a particular mold to found a final product. The features of the mixed rely on the pressure, class of recycled plastic and granulates [54,55,56].

3. Material properties

3.1. Recycled Low-Density Polyethylene (LDPE)

The supplier for Recycled Low Density Polyethylene (LDPE) provided the test properties of the material with respect to density, tensile strength at break, elongation at break, impact strength, and melting point of the material as shown below Table 1 [8,10]. Recycled low-density polyethylene (LDPE), which is identification number four, was gathered together and implemented in this research. The cleaned LDPE has shredded as shown below Figure 2.

Recycled Low-density polyethylene (LDPE) material is used extensively to produce tote bags for domestic goods. These bags become solid waste after their use for short periods and cause serious waste disposal problems. To solve this environmental problem, and at the same time to improve the drain down and other related engineering properties of the porous asphalt mixture, reclaimed from LDPE bags was used in this investigation as additive in porous asphalt mixtures. LDPE material in shredded of used is as added ingredient.

Recycled Low Density Polyethylene Features (LDPE)	
Mechanical Properties	
Yield Strength	15-20 MPa
Elongation @ break	600-650 %
Bending Strength	10-40 MPa
Young's modulus (E)	200-400 MPa
Shear modulus	100-350 MPa
Tensile Strength (σ_t)	8-12 MPa
Physical Properties	
Density	910-928 kg/m^3
Thermal expansion	150-200 e-6/K
Water absorption	0.005-0.015 %
Melting Point	248 ^{o}F 120 ^{o}C
Thermal conductivity	0.3-0.335 W/m.K
Melting temperature	125-136 ^{o}C
Maximum Temperature	176 ^{o}F 80 ^{o}C
Minimum Temperature	58 ^{o}F 50 ^{o}C
Specific heat (c)	1800-3400 J/kg.K

Table 1. Recycled Low Density Polyethylene Features (LDPE)

Figure 2. Shredded for recycled Low Density Polyethylene (LDPE)

3.2. Porous aggregate

Crushed limestone was chosen as the course aggregate for mixing LDPE. Bulk samples were sieved in conformity with the sieve sizes for AASHTO No. 8. According to Figure 3 demonstrates the gradation for aggregates that Porous aggregates confirming to the sizes 3/8 in., Nos. 4, 8, 16 (AASHTO No 8) were used for mixing with permeable plastic asphalt. Aggregates maintained on each sieve were washed, dried for 24 hours in 110°C in the oven and then located into their respective batches by sieve maintained. This procedure provided regenerate samples to meet AASHTO No. 8. Furthermore, it made to be better control over the gradation of each sample, so that gradation has important impact on the engineering and physical features of an aggregate mixed.

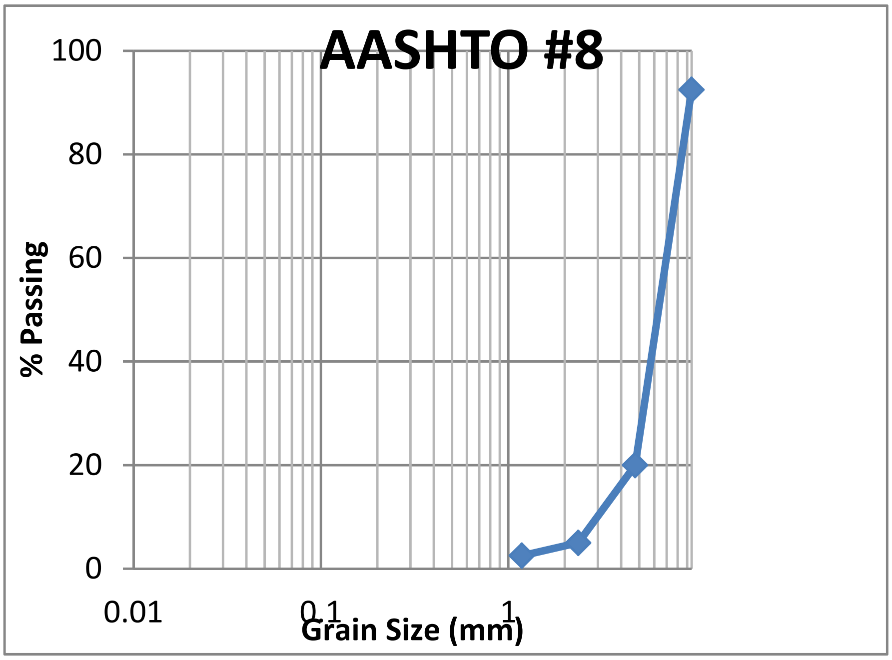

Figure 3. Grain size distribution of AASHTO No. 8

3.3. Bitumen

"PG 68-22" was used in the porous asphalt mixture [9]. Bitumen was mixed with Low-density polyethylene (LDPE) and porous aggregates. Mixes were prepared for three (4%, 5%, and 6% bitumen) percentages of bitumen. Each % of bitumen has 1% , 3%, and 6% LDPE. Obviously, four types of mixtures with three different percent of bitumen of 4%, 5% and 6% were used at a mixing and compacting temperature of 160°C. These are: Without LDPE, 1% LDPE, with 3% LDPE, and with 6% LDPE.

4. Samples preparation, compaction, and tests

4.1. Mixing of shredded waste plastic (LDPE), aggregate and bitumen

The aggregate mix is heated to 160°C in oven, and similarly the bitumen is to be heated up to a maximum of 160°C. Plastic waste is shredding for mixing bitumen and aggregate to coat the plastics effectively. After that, put them in oven 160^{0}C in order to mix and compact simultaneously. For protecting the moisture the spacemen, it compacted immediately after took out oven with approximately 160^{0}C.

4.2. Mix Design by Marshall method Marshall test

Use of the processed plastic bags is as an additive in bituminous concrete mixes. The processed plastic was used as an additive with heated bitumen in different proportions (ranging from 4 to 6 % by weight of bitumen) and mixed well by hand, to obtain the modified bitumen. The properties of the modified bitumen were compared with ordinary bitumen.

Varying percentages of waste plastic by weight of bitumen was added into the heated aggregates. Marshall sample with varying waste plastic content was tested for stability. Maximum value of stability was considered as criteria for optimum waste plastic content. The optimum modified binder content fulfilling the Marshall Mix design criteria was found to be 4, 5, and 6 % by weight of the mix, consisting of 1,3, and 6 % by weight of processed plastic added to the bitumen. In order to evaluate the ability of the mix prepared with the bitumen to withstand adverse soaking condition under water, Marshall Stability tests were conducted after soaking in water at 60^{o}C for 24 hours.

4.3. Porous plastic asphalt for preparation and compaction

Shedder LDPE was simultaneously composed with binder and aggregates for heating and mixing approximately 160^{o}C for two hours so that a uniform was achieved. Mixed plastic porous asphalt was poured and compacted into a mold, which is 4 inches diameter and 2.5 inches height, using a steel shovel. The Marshall test procedure was used for designing porous mix by compacting the sample with 50 blows on one face by Marshall hammer, at varying binder contents. The mixture design trials used asphalt content in the range of 4 – 6 %, by total weight of the mixture, excluding the weight of the fibers, with 1% increments. The LDPE fibers were added to the porous mixtures at a dosage rate of 1,3, and 6 % based on total mixture weight. The compacted samples were extracted from the mold when they had sufficiently cooled. After compaction, samples were be kept in the hot (conditioned) and cold (unconditioned) waters. Resilient Modulus and permameter test conducted. Samples were tested for hydraulic conductivity and indirect tensile strength. Figure 4 demonstrates the preparation of the Porous plastic asphalt samples.

4.4. Laboratory tests

Porous plastic asphalt samples were tested for hydraulic conductivity and indirect tensile strength. Hydraulic conductivity tests were operated using a falling head approach in conformity with a proceeding particularized in the researchers [57,58]. The indirect tensile tests were conducted in accordance with the ASTM C 6931-07 test methods.

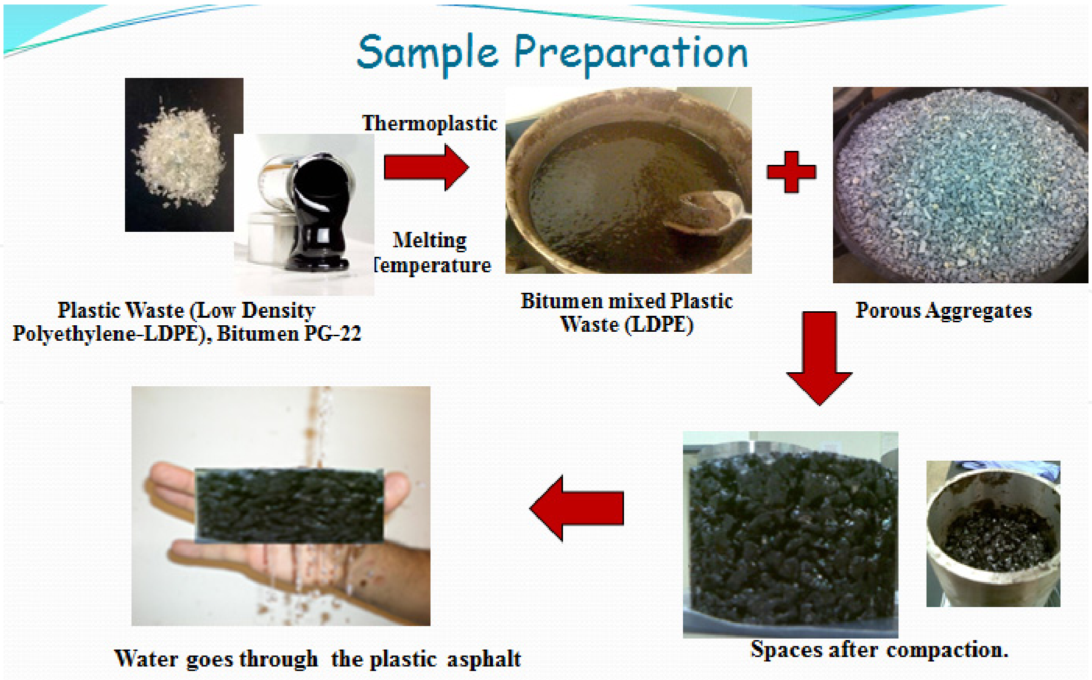

Figure 4. Figure 4 Sample preparation for permeable plastic asphalt that mixing of LDPE, porous aggregates, binder to create

From equation 1 calculate hydraulic conductivity for testing in the falling head permameater test. After used Permameters to measure k, use this following formula. Calculate the hydraulic conductivity of the sediment by using the following formula:

$$k = \frac{VxL}{(h_o - h)Axt} x ln \frac{h_o}{h} \tag{1}$$

where K = hydraulic conductivity of the sediment sample [L]/[T]
V = volume of water that passed through the sample $[L]^3$
L = sample length [L]
h0 = height of top mark above outflow port [L]
h = height of bottom mark above outflow port [L]
A = cross sectional area of sample. For the NEIU permameters, this is 31.65 cm^2. $[L]^2$
t = total time for discharge [T]

The indirect tensile test that is one class of tensile strength test implemented in order to stabilize elements. The test has been run on asphalt-stabilized elements [35,59,60,61]. The test has many advantages, the most obvious being simplicity of test procedure. From equation 2 calculate ITS for testing in the resilient modulus (MR) test. After used with the diametrical Mr test (repetitive indirect tensile modulus test) to calculate ITS, as using the tensile strength St of the material is given by:

$$S_t = \frac{2Pmax}{\pi td} \tag{2}$$

Where P= total applied load (lb)

t= sample thickness (in)
d= sample diameter (in)

5. Test results

5.1. Permeability

According to Table 2 demonstrates the hydraulic conductivity (k) of the porous plastic asphalt samples. From Table 2, it has provided that the results of k diminished with the growth of porous plastic mixing. For instance, when the results of k mixed %4 binders with %1 LDPE were 0.204 in/s, the result of mixing %3 LDPE was 0.193 in/s. Obviously, while mixing with % of LDPE was increasing, the result of k was diminishing. Figure 5 represents the results of permeability of porous plastic asphalt with mixing %1 LDPE.

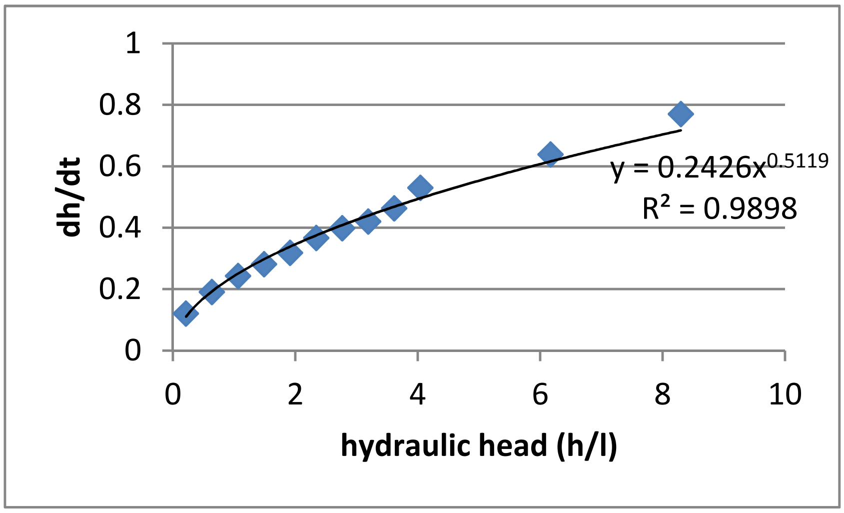

Figure 5. The results of k with mixing %1 LDPE

Binder	LDPE	k (in/s)
% 4	%0	0.217
	%1	0.204
	%3	0.193
	%6	0.178
% 5	%0	0.259
	%1	0.245
	%3	0.234
	%6	0.223
% 6	%0	0.301
	%1	0.294
	%3	0.288
	%6	0.272

Table 2. The results of hydraulic conductivity

5.2. Indirect Tensile Strength (ITS)

Use this test method to determine the tensile strength of compacted bituminous mixtures. The porous plastic mixed tested as a conditioned and unconditioned. After compaction, samples were kept in the hot water (conditioned situation) and cold water (unconditioned situation). The objective of this test was to measure the water resistance of the mixture after immersion for 24 hours at 60°C. After that, testing the resilient modulus provided the results of ITS. The purpose of results was to evaluate the resistance of porous plastic asphalt mix on plastic deformation. Furthermore, from equation 3 Tensile strength ratio (TSR) calculated that divided by conditioned to unconditioned situation. TSR < 70% considered Susceptible to Moisture. As a result it provides that the performance of strength of porous plastic asphalt. Moisture Susceptibility of Porous Plastic tested in accordance with ASTM C 6931-07. Samples were cured at room temperature, 100°C and 160°C for 24 hours. Samples dimension is Diameter=4″, Height=2.5″.

$$TSR = \frac{S1}{S2} \tag{3}$$

Where:

S1 = conditioned set (wet)
S2 = unconditioned set (dry)

According to Table 3 demonstrates that the results of unconditioned decreased with the growth of porous plastic mixing. For instance, when the results of mixed %5 binders with %3 LDPE were 57 psi, the result of mixing %6 LDPE was 54 psi. Obviously, while mixing with % of LDPE was increasing, the results of conditioned ITS was decreasing. On the contrary, the result of conditioned increased simultaneously with the growth of porous plastic mixing. Figure 6 represents that the result of conditioned ITS diminished while unconditioned ITS increased. According to the results of TSR is considered to susceptible to moisture. It provides that %3 LDPE and over is very strength.

Binder	**LDPE**	**Unconditioned (psi)**	**Conditioned (psi)**	**TSR (con/uncon)**
% 4	**%0**	**67**	**45**	0.67
	%1	**58**	**52**	0.90
	%3	**46**	**56**	1.22
	%6	**41**	**63**	1.54
% 5	**%0**	**71**	**54**	0.76
	%1	**62**	**59**	0.95
	%3	**57**	**62**	1.09
	%6	**54**	**68**	1.26
% 6	**%0**	**73**	**63**	0.86
	%1	**69**	**67**	0.97
	%3	**66**	**71**	1.08
	%6	**61**	**75**	1.23

Table 3. The results of Indirect Tensile Strength test (ITS)

The results of k and ITS of porous plastic asphalt mixtures were within the approximately predictable ranked come up in the literature for conventional asphalt showing Table 4. It is an indication that porous plastic asphalt should be used as a sustainable alternative for permeable pavements.

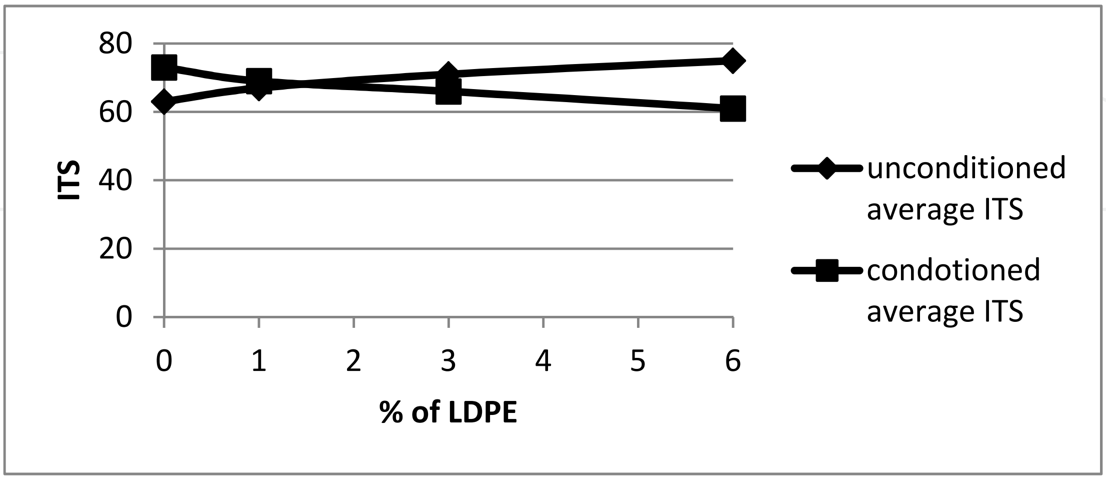

Figure 6. The results of ITS with mixing %6 LDPE

References	ITS ranges (psi)
[62]	29.29-69.76
[63]	18.17-38.82
[64]	253.9-377.09
[65]	29-65.26
[66]	26.1-130.53
[19]	18.30-55.90

Table 4. Summary of ITS porous asphalt from literature

6. Discussion and conclusion

Permeable Plastic Asphalt samples with different percentage of plastic to aggregate ratio were composed and then tested for hydraulic conductivity (k) and indirect tensile strength (ITS). Results represented which k and ITS results of samples were within the predictable results observed in the literature for porous pavements. In addition to it was come up with that the k, ITS values diminished as the percentage of plastic waste increased. The research results of Permeable Plastic Asphalt demonstrated that Permeable Plastic Asphalt should be a sufficient recycle and stormwater runoff with important reasonable economic and ecological associations.

This research was taken in charge to evaluate the hydraulic and mechanical features of innovative porous plastic asphalt for implementing in permeable pavements. The test represented that the result of hydraulic conductivity diminished with the growth of porous plastic mixing. On the other hand, while the results of unconditioned decreased with the growth of porous plastic mixing, the result of conditioned increased simultaneously with the growth of porous plastic mixing. Furthermore, the results of TSR are the best result over 1 for susceptible to Moisture. The results of experiments were approximately come across that expected from literature. According to results that demonstrate porous plastic asphalt could be implement sustainable alternative pavements. It also provides also recycling.

This research concentrated on the hydraulic and mechanical properties of a permeable pavement like permeable plastic asphalt. Permeable Plastic Asphalt was composed of plastic waste, aggregates, and asphalt. Permeable Plastic Asphalt should provide a sufficient method for decreasing stormwater runoff, contributing a structural pavement sufficient for pedestrian and vehicular loadings. Furthermore, Permeable Plastic Asphalt should take the part of the currently ongoing recycling aims as a critical role that support to deflect a majority of plastic from landfills and incinerators.

The laboratory test indicates that aggregate, binder with mixing LDPE affected the results of k and ITS. Thus, permeability and strength of porous plastic asphalt is getting better with mixing LDPE. It proves that porous plastic asphalt help to diminish storm water runoff times diminish urban heat island effects. A new pavement increases for the sustainability of the nature that will be benefit users for many years. The design of plastic pavements contains developed pedestrian and public transportation as well as parking lot, driveway, bridges.

The results represents porous plastic asphalt should be implemented as a sustainable alternative for permeable pavements. Porous plastic asphalt is a peerless choice in that it undertakes two environmental problems that decreasing stormwater runoff and prevent to fill out with plastic waste at landfills. In the way that we keep up our way to green building and construction, porous plastic asphalt is new approach on the way to eco-friendly improvement. The innovative technology comes to grips with two environmental problems that are plastic waste and stormwater runoff. It provides to prevent a large quantity of plastic waste at landfills and incinerators, thus the plastic waste uses fro recycling. Also it decreases stormwater runoff and decreases the use of natural resources.

Permeable plastic pavement has whole with its permeability should be determined by valid void. Valid void should be directly implement to mixing ratio of permeable plastic pavement that both take control sufficiently the forming of run off and restrict urban flood.

All above results that Landscape Engineering considers that the progress of permeable plastic uses to efficiently integrate the mixing permeable plastic pavements with land use planning. Using recycling service with very powerful has approached to create pleasing environments in the world. According to test results that the advantages of plastic asphalt provide that is stronger road with increased plastic, better resistance during stormwater, without stripping and rutting, develop binder and better linking of the mix. Besides it support that is the strength of the road is increased. Using permeable plastic asphalt that is the cost of road construction diminish the maintenance cost of road gradually diminish as well. Obviously, as the plastic mix with pavement for using, the disposal of waste plastic will no longer be issue. As a result of that, using plastic helps to decrease in pores in aggregate save bitumen and help recycling.

Consecutive chapters of this research will count profoundly on the outcomes of the test pavements mentioned above, as well as efficiency data issued in the research. Detailed representing results of the several researches projects will be debated during the research.

7. Future research

Effectively managing the collection, separation and processing of plastic waste can limit the environmental damages limited by eliminating the waste from our streets. Thus, we can prevent to fill the landfill with plastic waste when we mix the plastic with the other elements with soil, asphalt and cement in order to use future studies.

Laboratory tests and real life implementation will study that the life expectancy of a plastic polymer road as compared to a conventional road. Future study will need to study for expanding of life expectancy for plastic. This study proved that investigates, summarizes preliminary results, and debates key properties to be considered for future alternative pavement. Future researchers will keep going to research the better permeable pavement for economic, environmental and nature.

A long-term monitoring project to document changes in performance, evaluation of different maintenance strategies, and lifecycle costs of permeable plastic asphalts is recommended for future research. Future experience is based on designs that provide to improve future properties such as increased new materials, and developed construction and maintenance activities.

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8. References

[1] McKenna, GT. Sustainable Mine Reclamation and Landscape Engineering. PhD Thesis in Geotechnical Engineering, Department of Civil and Environmental Engineering, University of Alberta, Edmonton, 2002.

[2] American Society of Landscape Architecture. ASLA. http://www.asla.org/ppn/Article.aspx?id=1206&terms=landscape%20engineering (accessed 5 September 2012).

[3] American Society of Landscape Architecture. ASLA.

http://www.asla.org/uploadedFiles/CMS/Government_Affairs/Public_Policies/Licensure_Definition_of_Practice.pdf (accessed 5 September 2012).

[4] Zube E., Landscape Planning Education in America: Retrospect and Prospect. Landscape and Urban Planning, Volume 13, 1986, Pages 367–378, 1986.

[5] The LA Group, Landscape Architecture and Engineering P.C. http://www.thelagroup.com (accessed 8 September 2012).

[6] Valderrama A., Levine L., Yeh S., and Bloomgarden E., Financing Stormwater Retrofits in Philadelphia and Beyond, Natural Resources Defense Council (NRDC), February 2012. http://www.nrdc.org/water/files/StormwaterFinancing-report.pdf (accessed 11 September 2012).

[7] The plastics industry trade association. SPI Resin Identification Code - Guide to Correct Use. Washington. DC. http://www.plasticsindustry.org/AboutPlastics/content.cfm?ItemNumber=823&navItemNumber=1125 (accessed 2 November 2011).

[8] LDPE, Husky, 2008 Polly America, 2000 West Marshall Drive, Grand Prairie, Texas 75051, phone 800 527 3322, press 7654, www.poly-america.com (accessed 2 July 2011).

[9] Asphalt 64-22 cas no 8052-42-4 PG-2010-321, NuStar Asphalt Refining, LLC, 4Paradise Rd. Paulsboro, NJ 08066 phone 856 224 7405.

[10] Punith V. S., and Veeraragavan A., Characterization of Ogfc Mixtures Containing Reclaimed Polyethylene Fibers. Journal of Materials in Civil Engineering, ASCE, 341, March 2011.

[11] Khan A., Gangadhar, Mohan M., and Raykar V., Effective Utilization of Waste Plastics in Asphalting of Roads. Project Report Prepared Under The Guidance of R. Suresh and H. Kumar, Dept. of Chemical Engg., R.V. College of Engineering, Bangalore, 1999.

[12] Zaro G., Nystrom K C., Bar A., Alvarez A. U., and Miranda A., Tierras Olvidadas: Chiribaya Landscape Engineering and Marginality in Southern Peru, The Society for American Archaeology, Latin American Antiquity 21(4), pp. 355–374, 2010.

[13] Corner J., Representation and Landscape: Drawing and Making in The Landscape Medium, Word & Image 8, 246, July-Sept. 1992.

[14] American Society of Landscape Architecture. ASLA Security Design Symposium Abstracts. Chicago, IL, July 2004, http://www.asla.org/uploadedFiles/CMS/Resources/securitydesignabstractfinal.pdf (accessed 2 July 2011).

[15] Haselbach, L.M., Valavala, S., and Montes, F., Permeability Predictions for Sand-Clogged Portland Cement Pervious Concrete Pavement Systems, Journal of Environmental Management, 81, 42-49, 2006.

[16] Huang, B., Wu, H., Shu, X., and Burdette, E.G., Laboratory Evaluation of Permeability and Strength of Polymer-Modified Pervious Concrete, Construction and Building Materials, 24, pp. 818-823, 2010.

[17] Tennis, P.D., Leming, M.L., and Akers, D.J., Pervious Concrete Pavements. Porland Cement Association. 2004.

http://myscmap.sc.gov/marine/NERR/pdf/PerviousConcrete_pavements.pdf (accessed 2 July 2011).

[18] Montes, F., Valavaka, S., and Haselbach, L., A New Test Method for Porosity Measurements of Portland Cement Pervious Concrete, Journal of ASTM International, 2(1), 2005.

[19] Subagio B., Kosasih D., Busnial, and Tenrilangi D., Development of Stiffness Modulus and Plastic Deformation Characteristics of Porous Asphalt Mixture Using Tafpack Super™, Proceedings of the Eastern Asia Society for Transportation Studies, Vol. 5, pp. 803 - 812, 2005.

[20] Nakanishi H., Kawanaka T., Ziqing L., and Baocun H., Study on Improvement in Durability and Function of Porous asphalt Pavement, Road Construction, Japan, 2001.

[21] Daniels, S., and Repton H., Landscape Gardening and the Geography of Georgian England, New Haven, CT: Yale University Press, 1999.

[22] Harris D., and Hays D., On the Use and Misuse of Historic Landscape Views, in Representing Landscape Architecture, ed. Marc Treib., New York: Taylor and Francis, 22-41, 2008.

[23] Rieder K., Modeling, Physical and Virtual, in Representing Landscape Architecture, ed. Marc Treib., New York: Taylor and Francis, 2008.

[24] Waugh F. A. Landscape Engineering in the National Forests. US. Department of Agriculture Forest Service. 1918. http://archive.org/stream/landscapeenginee00waug#page/n1/mode/2up (accessed 5 October 2012).

[25] Doran, J.W., and T.B. Parkin. Defining and Assessing Soil Quality. In: J.W. Doran et al. (eds.) Defining Soil Quality for a Sustainable Environment. Soil Science Society of America, Madison, WI, Special Publication 35, pp. 3-22, 1994.

[26] Mollison B., Increases in Porosity Enhance Infiltration and Thus Reduce Adverse Effects of surface runoff, Permaculture: A Designer's Manual, Tagari Press, 1988.

[27] Hubbard, A. T., Encyclopedia of Surface and Colloid Science Vol 3, Santa Barbara, California Science Project, Marcel Dekker, New York, 2004.

[28] Beven K., and Robert E. Horton's Perceptual Model of Infiltration Processes, Hydrological Processes, Wiley Intersciences DOI 10:1002 hyp 5740, 2004. http://earth.boisestate.edu/jmcnamara/files/2011/10/KBeven_HP2004.pdf (accessed 23 August 2012).

[29] Stormwater Pennsylvania. http://www.stormwaterpa.org (accessed 25 August 2012).

[30] Busco D., and Lindsey G., An Annotated Bibliography of Stormwater Finance Resources, Center for Urban Policy and the Environment School of Public and Environmental Affairs Indiana University- Purdue University Indianapolis, April 29, 2002. http://stormwaterfinance.urbancenter.iupui.edu/PDFs/Biblio%204%2029%2002.pdf (accessed 26 August 2012).

[31] Lee J. H., and Bang K W., Characterization of Urban Stormwater runoff. Water Research. Volume 34, Issue 6, 1 April 2000, Pages 1773–1780

http://www.sciencedirect.com/science/article/pii/S0043135499003255 (accessed 23 August 2012).

[32] Dietza M. E., and Clausenb J. C., Stormwater Runoff and Export Changes with Development in a Traditional and Low Impact Subdivision. Journal of Environmental Management, Microbial and Nutrient Contaminants of Fresh and Coastal Waters, Volume 87, Issue 4, June 2008, Pages 560–566 http://www.sciencedirect.com/science/article/pii/S030147970700103X (accessed 23 August 2012).

[33] Canadian plastics industry association. http://www.plastics.ca/home/index.php (accessed 2 November 2011).

[34] Canadian plastics industry association. Environmental sustainability. http://www.plastics.ca/EnvironmentalSustainability/index.php/ (accessed 2 November 2011).

[35] Yoder E. J., and Witczak M. W. Principles of Pavement Design. Second Edition. John Wily And Sons, Inc, New York. 1975.

[36] Acum, W. E. A., and L. Fox, Computation of Load Stresses in a Three-layer Elastic System, Geotechnique, Vol. 2. pp. 293-300, 1951.

[37] McCullough, B. F., A pavement Overlay Design System Considering Wheel Loads, Temperature Changes, and Performance, Graduate Report, ITTE, University of California, Berkeley, 1970.

[38] Hveem, F. N., Pavement Deflections and Fatigue Failures, Highway Research Board Bulletin 342, 1962.

[39] Barber, E. S., Application of Triaxial Compression Test Results to the Calculation of Flexible Pavement Thickness, Proceedings, Highway Research Board, 1946.

[40] Fox, L., Computation of Traffic Stresses in a Simple Road Structure, Department of Scientific and Industrial Research, Road Research Technical Paper 9, 1948.

[41] McLeod, and Norman W., An ultimate Strength Approach to Flexible Pavement Design, Proceedings, Association of Asphalt Paving Technologist, 1954.

[42] Horner, and Raymond C., Effect of Base Course Quality on Load Transmission Through Flexible Pavements, Proceedings, Highway Research Board, 1955.

[43] Palmer, L. A., and E. S. Barber, Soil Displacement under Circular Load Areas, Proceedings, Highway Research Board, 1940.

[44] Poulikakis, L.D., and Partl, M.N., Evaluation of Moisture Susceptibility of Porous Asphalt Concrete using Water Submersion Fatigue Tests, Construction and Building Materials, 2009.

[45] Hassani, A., Ganjidoust, H., and Maghanaki, A., Use of Plastic Waste (Poly-ethylene Terephthalate) in Asphalt Concrete Mixture as Aggregate Replacement, Waste Manage Res 2005: 23: 322–327, 2005.

[46] Hinislioglu, S., and Agar, E. Use of Waste High Density Polyethylene as Bitumen Modifier in Asphalt Concrete Mix. Materials Letters, 58, 267-271, 2004.

[47] Zoorob S.E., and Suparman, L.B, Laboratory Design and Investigation of Proportion of Bituminous Composite Containing Waste Recycled Plastics Aggregate Replacement

(Plastiphalt), CIB Symposiumon Construction and Environment Theory into Practice, Sao Paulo, Brazil, November, 2000.
[48] Zoorob, S.E., Laboratory Design and Performance of Improved Bituminous Composites Utilising Plastics Packaging Waste", Conference on Technology Watch and Innovation in Construction Industry, Belgium, Building Research Institute, Brussels, Belgium, April, 2000.
[49] Conigliaro, A., and Watson, P., Determining the Best Formulation for a Unique Asphalt Cold Patch Product Made with # 3-7 Rigid Plastic Aggregate, Chelsea Center for Recycling and Economic Development Technical Research Program, January 2000.
[50] Mallick, R.B., and Teto, M., Evaluation of Use of Manufactured Waste Asphalt Shingles in Hot Mix Asphalt, 2000, Chelsea Center for Recycling and Economic Development Technical Research Program, July 2000.
[51] Sobhan, K., and Mashnad, M., Mechanical Stabilization of Cemented Soil–Fly Ash Mixtures with Recycled Plastic Strips, Journal of Environmental Engineering, ASCE, October 2003.
[52] Sobhan, K., Stabilized Fiber-Reinforced Pavement Base Course With Recycled Aggregate, Ph.D. Dissertation, Northwestern University, Evanston, Illinois, 303 pages, June, 1997.
[53] Cavey J. K., Krizek, R. J., Sobhan, K., and Baker, W. H., Waste Fibers in Cement-Stabilized Recycled Aggregate Base Course Material. Transportation Research Record 1486, Transportation Research Board, Washington D.C., 97–106, 1995.
[54] Meyers, III, Swartz, J, Nathaniel, Kurczewski, N., and Kurczewski, M., Recyclable Composite Materials Articles of Manufacture and Structures and Method of using Composite Materials, U.S. Patent No. 6,984,670, 2006.
[55] Malloy, R. and Kashi, M., and Swan, C., Fly Ash/Mixed Plastic Aggregate and Products Made Therefrom, U.S. Patent No., 6,669,773, 2003.
[56] Balkum, E , Aggregate Using Recycled Plastics, U.S. Patent No. 6,488,766., 2002.
[57] Fwa, T.F., Tan, S.A., and Chuai, C.T., Permeability Measurement of Base Materials using Falling-Head Test Apparatus, Transportation Research Record, No. 1615, pp 94-99, 1998.
[58] Khoury, N.N., Khoury, C.N., and Abousleiman, Y., Soil Fused with Recycled Plastic Bottles for Various Geo-Engineering Applications. ASCE Conf. Proc. 309, 42, 2008.
[59] Frocht, M. M., Photoelasticit, vol. 2 John Wiley and Sons, New York, 1957.
[60] Hadley, W. O, Hudson W. R., and Kennedy T. W., Evaluation and Prediction of The Tensile Properties of Asphalt-treated Materials, Highway Research Board Annual Meeting, Washington, D.C., 1971.
[61] Kennedy, J. W., and Hudson W. R., Application of the Indirect Tensile Test to Stabilized Materials, Highway Research Board Annual Meeting, Washington, D.C., 1968.
[62] Suresha S. N., George V., and Shankar A.U. R., Effect of Aggregate Gradations on Properties of Porous Friction Course Mixes, Material and Structure, 2010.
[63] Setyawan A., Design and Properties of Hot Mixture Porous Asphalt For Semi-Flexible Pavement Applications, Media Technic Sipil, July 2005.

[64] Liu Q., Schlangen E., Garcia A., and Ven M. V.D., Induction Heating of Electrically Conductive Porous Asphalt Concrete. Construction and Building Materials, 2010.
[65] Shen D., Wu C., and Du J., Laboratory Investigation of Basic Oxygen Furnace Slag for Substitution of Aggregate in Porous Asphalt Mixture. Construction and Building Materials 23, 2009.
[66] Xiao F., Zhao W., Gandhi T., and Amiskhanian A. N., Influence of Antistripping Additives on Moisture Susceptibility of Warm Mix Asphalt Mixture. Journal of Materials in Civil Engineering, October 2010.