International Journal of Advanced Science and Technology
Vol.67 (2014), pp.11-22
http://dx.doi.org/10.14257/ijast.2014.67.02

Effects of Human Hair Additives in Compressive Strength of Asphalt Cement Mixture

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Abstract

This experimental study presents the effects of human hair additives in compressive strength of asphalt cement mixture as potential binder in road pavement. Human hair is strong in tension and can be used as a fibre reinforcement material. Hair Fibre (HF) is an alternate non-degradable matter is available in abundance and at a very cheap cost. It also creates environmental problem for its decompositions. This elastic property of the HF reinforced in asphalt pavement may produce better stand on traffic loading by the same fundamental mechanism of transferring the high intensity forces imparted at the surface by the wheel loads to lower levels that the subgrade can accommodate without deforming.

The experiments made were asphalt mixture with human hair as the experimental group and standard asphalt mixture being the control groups. Human hair added to standard asphalt mixture with three different proportions varying from 3% to 12% by mass of with respect to bitumen.

This study proves that adding cement and human hair to asphalt mixture greatly increase the strength of the mixture thus making it a good material for the construction of road pavement. Adding of both cement and human hair to asphalt mixture improves the load bearing capacity of the mixture.

Keywords: *Coarse aggregate, construction material, pelletized cut rubber, scrap waste tire*

1. Introduction

During the last seventy years in Manila, there was an unprecedented development in infrastructure, particularly on roads. Many thousands of kilometers of new roads were constructed worldwide to meet the demands of increasing traffic volumes. Many of these roads have been used for more than twenty years and have reached the end of their design lives, requiring increasing maintenance efforts to retain acceptable levels of service. In addition, the average vehicle mass has steadily increased over the years as more goods divert from rail and sail to the more flexible and faster road transport. Increased traffic pressures, higher axle loading and old age contribute to road deterioration.

As the turn of millennium approaches most countries are facing similar problems with their road networks. An increasing proportion of road budgets are required just to maintain existing roads and there is consequently less money available for rehabilitation measures or new construction. In many countries like Philippines there is simply not enough money to keep pace with maintenance needs, resulting in rapid decline and more expensive rehabilitation measures that will eventually be required to

ISSN: 2005-4238 IJAST

restore service levels. New roads, or upgrading projects, can often only be considered if toll revenues justify the capital outlay. It is a downward spiral.

This break scenario presents a challenged to roads engineers. The World Bank and other institution have shown that any nation needs a sound infrastructure for economic health and good roads are vital part of that infrastructure. If the funds available are insufficient to rescue the current crisis then a more cost-effective method of road rehabilitation must be found. Innovation is required to find alternative construction methods that will increase the effectiveness of existing budget, thereby achieving more square meters of roads. Asphalt-cement with hair road pavement is one such alternative.

The major emphasis of this study is to describe the change in the properties of asphalt when it mixed with cement and hair. Hair was used as polymer. Hair contains a high amount of sulfur because the amino acid cysteine is a key component of the keratin proteins in hair fiber [1, 2]. The primary component of hair fiber is keratin. Keratins are proteins, long chains (polymers) of amino acids. In terms of raw elements, on average, hair is composed of 50.65% carbon, 20.85% oxygen, 17.14% nitrogen, 6.36% hydrogen, and 5.0% sulfur [2].

The researcher focus on this study in ordered to lessen the waste and to get an additional strength from those human hairs. With this, the researcher could help manage the solid waste, like human hair, orderly. Because if the human hair will be separated from the waste of the environment it will be in order, if this will be done, sickness could also be lessen and the rehabilitation of pavement becomes cost-effective.

2. Literature Review

2.1. Human Hair Additives

There are many additives to make concrete better, set faster, set slower, make stronger and reduce corrosion. The Romans discovered that adding volcanic ash produced a concrete which would set under water. The Romans also knew that adding horse hair made concrete less liable to crack as it set, and that adding blood made it more frost-resistant [1, 2]. Hair is used as a fibre reinforcing material in concrete for the following reasons: (a). It has a high tensile strength which is equal to that of a copper wire with similar diameter. (b) Hair, a non-degradable matter is creating an environmental problem so its use as a fibre reinforcing material can minimize the problem. (c) It is also available in abundance and at a very low cost. iv. It reinforces the mortar and prevents it from spalling.

It is well known that hair has a relatively high tensile strength, and whilst it has previously been proposed to mix cut strands of animal hair as a binding material into plaster or concrete based products, it is the case that hair has otherwise largely been discounted for use as a structural material [3, 4]. In contrast, it has been commonplace to use other fibre-based composite materials, such as glass reinforced plastic (known as GRP or fiberglass). Such materials have a mechanical strength which can exceed that of a hair based composite, but as they are not biodegradable they can only really be disposed of (in an economical fashion) by consigning them to landfill, and as such they are relatively environmentally unfriendly [5, 6]. This problem is particularly prevalent in the clothing retail industry, as many thousands of mannequins (typically of fiberglass) are replaced every year. As there is no effective way to economically recycle old waste mannequins, they are typically consigned to landfill where they pose a significant environmental problem. Some of the more progressive retail companies have appreciated this problem and would like to purchase more environmentally friendly (or at least environmentally benign) mannequins, but commercially acceptable alternatives are not currently available[7, 8, 10]. Other composites in use today are made from petroleum-based products, and to reduce reliance upon finite petroleum resources it has been proposed to use composites such as MDF (a chipboard wood derivative). However, composites such as MDF may be carcinogenic, and as such it would be advantageous if an alternative composite material could be devised [9, 11].

In one envisaged implementation, collected hair cuttings may be cleaned in acetone, carded, and then weaved on a spindle into a twine. The hair twine can then be weaved into webbing or matting which forms at least one component of the aforementioned base material for use in the manufacture of the composite [1, 13]. In an alternative arrangement the base material may comprise loose strand felting manufactured from waste hair cuttings by any of a number of known methods, and this felting can then be used with a structural additive as hereinbefore described to form a composite [14]. In particular, the base material may be combined with a liquid resin as the structural additive, so that on curing the resin acts to set the base material in a desired configuration and to reinforce the composite. In a particularly preferred arrangement, the structural additive may comprise a biocompatible, eco-friendly and preferably recyclable bio-resin [15-17]. Advantageously, a composite formed from such material would then be biodegradable, recyclable, sustainable, and eco-friendly. As an alternative to including the aforementioned hair-based base material in a composite material, it will be apparent to persons of ordinary skill in the art that the base material may be put to a variety of different uses [18, 19]. For example, the base material could be used in the manufacture of blankets, clothing, armor, building fabric, organic compost, or compost blanket (such as a seed mat) for supporting the growth of micro-organisms .

The base material could also be used for the manufacture of medical devices, for example components such as replacement body parts (*e.g.,* hip joints) or parts thereof, in conjunction with a structural additive that is suitable for use within the body. There may also be applications where the base material itself, without an applied structural additive, would be of utility [20].

In a particularly preferred arrangement the composite may comprise a polymeric or starch based resin as the structural additive for a human hair-based web or mat of random lengths of human hair held in a mat or web like configuration by a resin-dissolvable binder material. In another arrangement, the composite may be formed by rolling out a collection of random lengths of hair, typically onto a board, to ensure even material density and constant flatness / thickness[2, 21]. Then a suitable binder may be applied to the hair to bind individual hairs together and thereby form a flexible, generally contiguous mat of hair. The mat may then be cut or stippled to the shape of a product to be molded and a chosen structural additive such as a resin, for example, may be applied to the base material by any of a number of previously proposed processes, for example one of those used in the manufacture of glass reinforced plastic [22].

Assembly of hair lengths maybe accomplished by mechanically interlinking or otherwise joining the hair lengths, by adhering lengths of hair together, or by treating the hair lengths so that they naturally tend to interengage with one another. In one envisaged implementation, the mat is laid up into a mound and then trimmed (for example with a pair of scissors) to confirm to the shape of the mound [2]. The structural additive is then applied to the laid-up mat (for example by painting the additive onto the mat, by filling the mound with additive or by spraying the mat with additive), and the resulting composite is cured to yield a substantially rigid body.

2.2. Asphalt Binder

Asphalt binder is typical categorized by one or more shorthand grading system according to their physical characteristics. These systems range from simple to complex and represent an evolution in the ability to characterize asphalt binder. Today, most State uses the Super pave Performance Grading (SPG) system, although brief mention of the older system is still worthwhile [1, 3]. The two major historical grading systems (old) use in U.S. is penetration grading and viscosity grading. Penetration grading is based on the depth of a standard needle will penetrate an asphalt binder sample when placed under a 100g load per 5 seconds. The test is simple and easy to perform but it does not measure any fundamental parameter and can only characterize asphalt binder at one temperature (77°F) [3]. Penetration grades are listed as a range of penetration units (one penetration unit equals to 0.1mm). Typical asphalt binders used in U.S. are 65-70 pens and 85-100 pens [3]. Viscosity grading measures penetration (as in penetration grading) but also measures an asphalt binder viscosity at 140°F and 275°F. Testing can be done on virgin (AC) or aged (AR) asphalt binder. Grades are listed in poises (cm-g-s =dyne-second/cm-cm) or poises divided by 10 [2, 3]. Typical asphalt binders used in the U.S. are AC-10, AC-20, AC-30, AR-4000 and AR-8000 [3]. Viscosity grading is a better grading but it does not test low temperature asphalt binder rheology. The new grading system, the Super pave PG system was developed as part of the Super pave research effort to more accurately and fully characterized asphalt binders for use in HMA pavements[3, 21]. The PG system is based on the idea that an HMA asphalt binders, this involves expected climatic conditions as well as aging considerations. Therefore, the PG system uses common battery of test (as the older penetration and viscosity grading system do) but specific temperatures that are dependent upon the specific climatic conditions in the area of intended use. Therefore, a binder used in Northeastern Washington would be different than one used in Northwestern Washington. Super pave performance grading is reported using two numbers, the first being the average of seven days maximum pavement temperature (in °C) and the second being the minimum pavement design temperature likely to be experienced (in °C) [1, 3]. Thus, a PG 58-22 is intended for use where the average seven days maximum pavement is 58°C and the expected minimum pavement temperature is -22°C. Notice that these numbers are pavement temperatures and not air temperatures. If no other information is available, these grades should be the default choices for use in HMA [3].

Some asphalt cement mixture requires modification in order to meet specifications. Asphalt cement modification has been practiced for over 50 years but has received added attention in the past decade or so. There are numerous binder additives available on the market today. The benefits of modified asphalt cement can only be realized by a judicious selection of the modifiers and not all modifiers are appropriate for all application. In general, asphalt cement should be modified to achieve the following types of improvements [3]: (a) Lower stiffness or viscosity at the high temperatures associated with construction. This facility will pump the liquid asphalt binder as well as mixing and compaction of HMA. (b) Higher stiffness at high service temperatures. This will reduce rutting and shoving. (c) Lower stiffness and faster relaxation properties at low service temperatures. This will reduce thermal cracking. (d) Increased adhesion between the asphalt binder and the aggregate in the presence of moisture. This will reduce the likelihood of stripping and it result in good aggregate-asphalt binder adhesion.

2.3. Cement

ASTM C150 defines the cement as hydraulic cement (cement that not only hardens by reacting with water but also forms a water-resistant product) produced by pulverizing clinkers consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an inter-ground addition [14, 16]. Clinkers are nodules of a sintered material that is produced when raw mixture of predetermined composition is heated to high temperature. The low cost and widespread availability of the limestone, shale, and other naturally occurring materials make Portland cement one of the lowest –cost materials widely used over the last century throughout the world. The manufacture and composition of Portland Cements, hydration processes, and chemical and physical properties have been repeatedly studied and researched, with innumerable reports and papers written on all aspects of these properties. Different types of Portland cement are manufactured to meet different physical and chemical requirements for specific purposes, such as durability and high-early strength [15, 19]. Eight types of cement are covered in ASTM C150 and AASHTO M85. ASTM C150 and AASHTO M85 have specified certain physical requirements for each type of cement. These properties include fineness, soundness and consistency, setting time, compressive strength, heat of hydration, specific gravity, and loss of ignition [12, 17]. Each of these properties has an influence on the performance of cement in concrete. The fineness of the cement, for example, affects the rate of hydration. Greater fineness increases the surface available for hydration, causing greater early strength and more rapid generation of heat. AASHTO M85 requires coarser cement, which will result in higher ultimate strength and lower early-strength gain [19]. The Wagner Turbid meter and the Blaine air permeability test for measuring cement fineness are both required by the ASTM and AASHTO. Average Blaine fineness of modern cement ranges from 3,000 to 5,000 cm^2/g (300 to $500m^2/kg$). Soundness, which is the ability of hardened cement pate to retain its volume after setting, can be characterized by measuring the expansion of mortar bars in an autoclave (ASTM C191, AASHTO T130) [3, 21]. The compressive strength of 2-inch mortar cubes after seven days (as measured by ASTM C190) should not less than 2,800 psi or 19.3 Mpa. Other properties included are specific gravity and false set. False set is a significant loss of plasticity shortly after mixing due to the information of gypsum. In many cases, remixing concrete before it is cast can restore workability [22].

2.4. Glass as an Additive Material for Asphalt

Glass makes up approximately 7 percent--approximately 12 million t (13.2 million T)--of the total weight of U.S. municipal solid waste discarded annually [18]. Approximately 20 percent of this glass is being recycled, primarily for cutlet in glass manufacturing. The ability to use glass in highway construction depends on the types of collection methods used, costs, and public factors. In general, the large quantities of waste glass needed for such application are found only in major metropolitan areas.

Many highway agencies routinely allow glass to be used as a substitute for aggregate in asphaltic concrete pavements. For example, New Jersey Department of Transportation (NJDOT) specifications allow the substitution of up to 10 percent glass (by weight) for aggregate in asphalt base courses [19, 23]. The department placed two sections of asphalt surface courses of about 0.5 kilometers (0.3 miles) each containing 10 percent glass. One of the sections contained an anti-strip additive; the other did not. Results to date indicate that both of these sections are performing as well as conventional pavement.

The Clean Washington Center of Seattle has conducted laboratory tests on glass cutlet for compaction, durability, gradation, permeability, shear strength, specific gravity, thermal conductivity, and workability as a construction aggregate [18, 21]. The center has subsequently developed recommendations for the approximate percentages of glass to be used for different applications.

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2.5 Use of Plastic in Plasphalt or as an Asphalt Cement Additive

Plastics have been analyzed for a variety of construction related products. As reported by a team of engineers before the Materials Engineering Congress, unsaturated polyester resins based on recycled PET #1 offer the possibility of a lower source cost of materials to form useful polymer concrete for a binder and mortar products to replace natural aggregates. Granulated plastic was used in a Portland-cement concrete structure in Elgin IL; and a "pedestrian bridge deck contained 30 percent plastic as a partial replacement of sand to reduce dead weight at comparable compressive strength [22]".

The plastic resin, LPDE, has been recycled into pellets to modify asphalt mixes. Colorado, Nevada and New York installed road pavements with LPDE pellets mixed in conventional hot-mix plants at about 7 percent by weight of polyethylene to asphalt cement. Western Plasphalt Products has conducted tests and patented several products that combine various types of unsorted waste plastic and incorporates the granulated material for seven to ten percent of the medium-sized aggregate in a typical asphalt cement mix [18, 19].

Due to the abundance of discarded tires, many states have pursued the reuse of rubber in tires. Crumb Rubber is a product used in asphalt binders. A rubber tire-plastic composite was tested and found to be less reactive than a crumb rubber binder, with more stability when stored at high temperatures [20].

Glass and plastic are proven quality additives to asphalt mixes. Their reuse as additives to asphalt cement mixes enabled many communities to lessen their waste output [21, 23]. Experiments and tests show that these materials improve the quality of asphalt cement mixes as applied in road pavement construction. Further studies are needed to develop these materials to more economical and dependable substitute to conventional asphalt cement mixes aggregates and additives

3. Methodology

As shown in Figure 1, the experiments made were asphalt mixture with human hair as the experimental group and a standard asphalt mixture being the control groups. The experiments made were of three different batches of asphalt-cement-hair mixture specimens, as to the percentage of hair being proportioned to the mass of bitumen. The three batches have 3, 6, and 12 percentages by weight of bitumen of hair, respectively. Also, a sample batch with standard mix design of bitumen is made, to provide for strength comparison.

3.1. Experimental Procedure

The procedure describes the mix design of granular materials using a combination of cement and asphalt. The effect of hair as fibre in asphalt cement mixture can be determined in the following tests.

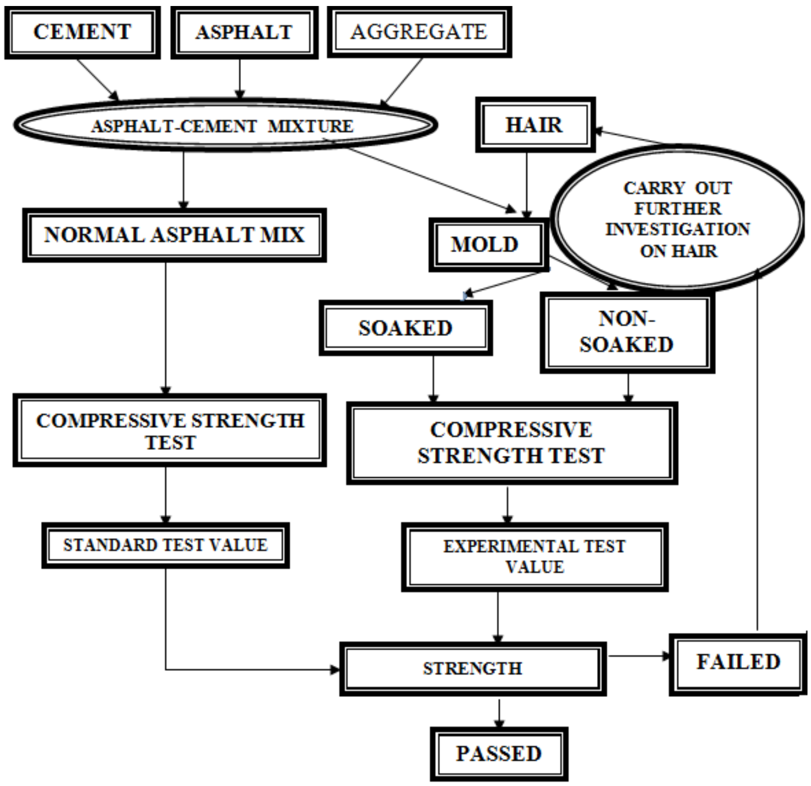

Figure 1. Conceptual Framework

3.1.1. Determination of Optimum Fluid Content and Testing: (a) Carry out standard tests to determine the grading and plasticity index (PI) of the aggregates. (b) Adjust the grading if necessary to meet any grading envelope requirements. (c) Determine the optimum moisture content as per modified moisture-density relationship test (AASHTO designation T180) and oven-dry material to constant mass at 105^{0}C. (d) When dry, riffle the sample and weigh into two 1 kg per batches. (e) Add between 1 and 2 % cement or lime to the sample, depending on the PI. Higher percentage of lime should be considered where the PI is greater than 10. (f) Heat the asphalt in bowl with greater temperature of 180^{0}C to 200^{0}C. (g) Add the required percentage by mass of lime or cement in the prepared aggregates in discharge it to the bowl. (h) Mix the aggregates and asphalt in the bowl for thirty minutes. (i) While continue mixing, prepare the mould and hammer by cleaning the mould, collar, base plate and face of the compaction hammer. (j) Place a round paper disc at the bottom of the mould. (k) Transfer the mixture to the mould and compact the mixture by applying 75 blows with the compaction hammer. Care must be taken to ensure the free fall of the hammer. (l) Remove the mould and collar from the pedestal, and invert then compact the other face with a further 75 blows. (m) After compaction, remove the mould at room temperature before extruding it. (n) Place the samples on a smooth flat tray and cure for further 72 hours under the sun or 40^{0}C.

3.1.2. Determination of indirect tensile strength (ITS): (a) Measure the height of each specimen at four evenly spaced places around circumference and calculate the average height. (b) Measure the diameter of each specimen. (c) Place the specimen into the loading apparatus. (d) Position the sample such that loading strips are parallel and centered on the vertical diametrical plane. (e) Place the transfer plate on the top bearing strip and apply the load to the specimen, without shock, at a constant rate until the maximum load is reached. (f) Record this load, P (KN), accurate to 0.1KN in order to determine the ITS for each specimen to the nearest 1KPa.

As the ITS were determined in each samples. Another laboratory experiment was made by adding hair on the asphalt cement mixture. For making this experiment, the above procedures were made except that the hair is placed after thirty minutes mixing. Three batches were made with 3%, 6% and 12% by weight of bitumen of hair for each batch. Testing and documentation followed.

4. Results and discussion

It is clearly shown that the asphalt-cement with hair is much stronger compared to asphalt-cement mixture only because hair act as an additional binders like a polymer. As shown in Figure 2, asphalt-cement mixture treated in dry condition performed much better than the asphalt-cement mixture treated in soaked condition in terms of compressive strength because the asphalt is a product of petroleum and the water reduces the bond between asphalt and aggregates thus decreasing its strength.

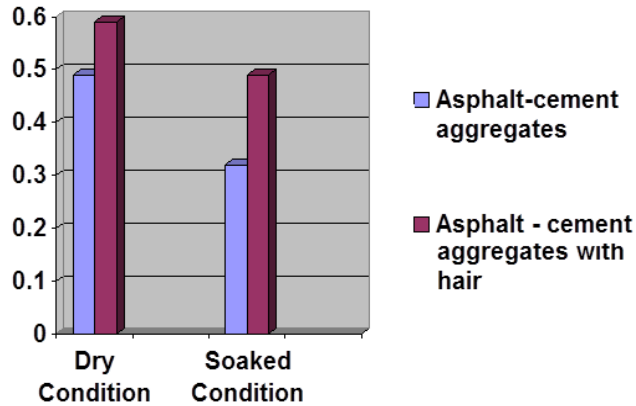

Figure 2. Strength of Asphalt-cement Mixtures

Table 1 shows that there is a large probability of deterioration of the specimen if the amount of hair to be added is 8% or more by mass of bitumen. One probable cause for this is that hair fibers carry more loads than the surrounding asphalt, and since hair becomes brittle when heated, the whole asphalt-cement mixture with hair also becomes more brittle. However, an amount of hair greater than 8% may be added to the mixture if a slight modification is done. The hair may be added after allowing some time for the asphalt-cement mixture to cool. This may offset the effect of heat on the hair thus making the mixture more resistant to loads.

Table 1. Compressive strength test

ASPHALT MIXTURE DESIGN	DRY CONDITION (KPa)	SOAKED CONDITION (KPa)
Standard asphalt-cement mix design	0.49	0.32
Asphalt-cement with hair 3% by mass of bitumen	0.58	0.49
Asphalt-cement with hair 6% by mass of bitumen	0.59	0.51
Asphalt-cement with hair 6% by mass of bitumen	0.31	0.26

5. Conclusions

It is also concluded that the varying condition on road pavements greatly affects the strength of asphalt mixture. Another thing is that the addition of hair to the asphalt cement mixture greatly improves its capability to bear more loads applied to it. Additional hair must range from 2% to 6% by mass of bitumen or else the mixture would have lesser bond and becomes unstable. Moreover, the properties of asphalt pavement with hair is suitable to road pavement, the hair becomes the additional binder, which exhibits superior resistance to both deformation and fatigue. The asphalt should be mixed and slightly cooled to avoid the awful odor of burnt hair. To meet the desired mixture, reduce the size of the hair waste into smaller one. It is also recommended to increase the percentage of asphalt content. The source of aggregates must be in good quality. It is recommended to use a good type of asphalt in terms of its size and shape. The required temperature must be strictly observed. Moreover, it should be tried not only to horizontal construction but also in vertical construction. Finally, the researcher recommend that further studies be made about this subject to better improve on the product

Appendix

Figure 3. Processing of human hair waste

Figure 4. Asphalt-cement and asphalt-cement-hair mixtures

Figure 5. Compressive Test

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