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ENVIRONMENTAL IMPACT AND USE OF WASTE MATERIALS IN HIGHWAY CONSTRUCTION

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Abstract

With the improvement of the highway industry and traffic growing on the highways, construction materials have also been evolved and more unconventional ingredients have been incorporated. Naturally available materials like gravel, aggregates, soil, sand, stone etc. have been used for construction of highway. Subsequently, as the civilization grew, some of the naturally available materials were processed further to derive new binding materials like, bitumen, cement etc. due to considerable usage of various naturally occurring materials for building road and other infrastructures, these have started depleting gradually. An assessment based on economic, technical and environmental factors has indicated that reclaimed paving materials, coal fly ash, blast furnace slag, bottom ash, boiler slag, steel slag, and rubber tire have significant potential to replace conventional material for various applications in highway construction and should be projected for future construction. Specific applications of the waste product and the potential problems associated with their usage in highway operations, which must be addressed before their extensive use, are included. The practice of incorporating certain waste products into highway construction and repair materials (CRMs) has become more popular. These practices have prompted the National Academy of Science, National Cooperative Highway Research Program (NCHRP) to research the possible impacts of these CRMs on the quality of surface and ground waters. State department of transportations (DOTs) are currently experimenting with use of ground tire rubber (crumb rubber) in bituminous construction and as a crack sealer. Crumb rubber asphalt concrete (CR–AC) leachates contain a mixture of organic and metallic contaminants. This study presents the environmental impact and use of some waste materials on construction of highways.

Keyword: waste glass, rubber tires, slag, impact of waste materials, recycling waste materials

1. Introduction

Historically, cement, soil, gravel, sand, bitumen, etc. are used for highway construction. Natural materials being consumable in natures and its quantity is declining gradually. Also, cost of well quality of natural material is increasing. As the world population grows, so the amount and type of waste materials are arising and being generated. most waste materials can be used either as a stabilizing agent in soil and subgrade applications or as an additive to aggregates blends in hot mix asphalt pavement. hundreds wastes produced today remain in the environment, perhaps thousands of years. The creation of no decaying waste materials, combined with a growing consumer population, has resulted in a waste disposal crisis. One solution to this crisis lies in recycling waste into useful products. The highway works are usually concerned with displacement of huge amount of soil and it is usually needed to deliver lacking material from outer supply. In this case, highway engineers, basing on economic criteria, reach to the closest mineral deposit available. If the deposits are not available, it turns out that usage of waste materials is more economically feasible, if the deposits are located close to construction site. This is the genesis of large scale waste material usage in the highway works, in the highway fill construction. Recycling materials have been reported to be utilized in different composition in different layers of highway structure from the top surfacing layer to the underneath layers. The processing cost, the engineering properties, the evidence that demonstrate the viability of the material and its positive impact on the long-term performance of the highway construction works are what characterizes and favors the use of that specific recycled waste material. It is of the essence to properly understand the behavior of any recycled by-products, and investigate the influence on the proposed inclusion with a construction material in order to come with a suitable and viable utilization with regards to type of material and the employed dosage.

2. Future scope

Nowadays, the disposing of waste materials has become a vast problem. For instance, Crumb rubber is a waste material which produced by shredding and commutating used tires. Approximately higher amount of waste tires is disposed of via urban and rural areas. This causes various environmental problems including air pollution (due to burning of tires) and aesthetic pollution which causes severe health related issues. These are a biotic, disposable product due to which these materials pose environmental pollution. In recent years, by-products of rubber wastes are being used in highway construction with great interest in many developing countries. The selection of these materials in highway construction is based on technical, economic, and ecological criteria and is giving a fruit. Every year million tons of rubber waste are produce in the world. Utilizing of these materials in highway construction can successfully reduce the pollution and disposal problems. It's also necessary to examine these waste materials and to develop specifications to increase the use of these materials in highway making, in which higher economic returns may be possible. These materials should be used in highway construction in each and every part of world. The waste tires can be used in the form of aggregate which on mixing with various bitumen in suitable size. This reduces the pollution occurred due to waste tires as well as minimizes the use of natural aggregate, which help in reducing global warming as well as health problems.

3. Background

Athira R Prasad etal (2015) Says that the bitumen which is conventional material used in the road construction can be partially replaced by the waste plastic and rubber. They added rubber and PET in 3%, 4.5%, 6%, 7.5%and 8% in bitumen and found that the optimum content was obtained at 6%. Thus according to their study the use of plastic in 6% by weight of bitumen improves the pavement stability. And they found the use of PET bottle is best. Therefore, the disposal of rubber and PET is best in the road construction.

Sasane Neha .B etal (2015) Explains that the addition of plastic is the innovative technology which strengthen the road construction and also increases the life of road. As the plastic content increase the property of bitumen and aggregate also increases compared to conventional flexible pavement the flexible pavement with the added plastic has good results. According to marshal stability test the optimum use of plastic is up to 10%.

S.Rajasekaranetal (2013) Explains that by coating the aggregate with the polymer has many advantages and which ultimately helps in improving the flexible pavement quality not only it improve the pavement quality but also improve the aggregate quality. This technology also helps in the disposal of waste plastic obtained from the domestic and industrial packing materials. The dry process is more valuable as it dispose the 80 % of waste polymer in eco-friendly way. And use of polymer reduces the equivalent bitumen quantity and therefore reducing the construction cost of road.

The paper by **Bambang S SUBAGIO, Djunaedi Kosasih et.al**.(2005) on "Development of Stiffness Modulus and Plastic Deformation Characteristics of Porous Asphalt Mixture Using Tafpack Super concludes that the Tafpack Super which was used as an additive in a porous asphalt mix improves the mechanical properties of the mix such as increase in resilient modulus and tensile strength and also improves resistance to permanent deformation.

Soni& Punjabi (2013) the consumption of waste polythene in bituminous concrete mixture thus formed. The waste polythene consumed in the mix will get coated over aggregates of the mixture and reduces porosity, absorption of moisture and improves binding property, the bitumen modified with 4.5% polythene waste id showing better performance as compared to other mixes.

Onyango (2015) Crumb rubber of sieve fraction 2.36 mm was used to substitute a fraction of the fine mineral aggregates of similar sieve size (2.36 mm) so that the overall grading was maintained. Proportions of 0%, 1% 2%, 3%, 4% and 5% of crumb rubber by weight of the aggregates were used in the asphalt mix and desired plastic to asphalt ratio was added from 2-10% by weight of bitumen. At the result highest flow values are exhibited by 5% crumb rubber and 10% LDPE content.

4. Materials

4.1. Waste Glass

Glass is a transparent material formed by melting a mixture of materials such as silica, soda ash, and $CaCO_3$ at high temperature followed by cooling during which solidification occurs without crystallization. When waste glass is crushed to sand-like particle sizes, similar to that of natural sand, it exhibits properties of an aggregate material. With the rapid economy growth and continuously increased consumption, a large amount of glass waste materials is generated. The Marshall design was used to examine the influence of the Optimum Asphalt Content (O.A.C.) at different fine glass percentages and the resistance against water. Asphalt-concrete mix properties can be improved by using a hydrated lime admixture and other mixtures. It is expected that the recycling and use of waste glass in asphalt mixes is feasible. Subsequently, by obtaining low price and economic mixes that will reduce the O.A.C., increase the stability and the durability of the mix, in addition to increasing

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the skid resistance of the road surface, this will reduce accidents and save a lot of money. By crushing and sieving, waste glass materials can be used as fine aggregates in asphalt concrete, where this is called glassphalt. Satisfactory performance of upper asphalt pavement layers can be achieved by adding glass waste of the mix. Table 1 present the types of glass and their main uses. There are two types of waste glasses; colored and colorless. Most colorless waste glasses are recycled effectively. Colored waste glasses with their low recycling rate are generally dumped into landfill sites. However, with the shortage of landfill sites, land filling is becoming more and more difficult. Since the glass is not biodegradable, landfills do not provide an environment-friendly solution. Therefore, there is strong need to utilize waste glasses.

Type of glass	*Main Products*
Soda lime glass	Bottles and jars Tableware Flat glass
Lead glasses	Crystal tableware Television screens and display screen equipment
Borosilicate glasses	Glass fiber Wool insulation Ovenware
Technical glasses e.g. *Alumina-silicate,* *Alkali-barium*	Scientific Frits Optical

Table 1: Types of glass and their main uses

4.1.1. properties of Waste glass

Common glass contains about 70% SiO2. Glass-formers are those elements that can be converted into glass when combined with oxygen. The use of glass in unbound aggregate base layers is technically feasible. However, the use of glass as an aggregate will require it to be crushed to the appropriate gradation and pretreated if the level of contamination is not within acceptable limits. The economics of using glass in embankments depend on the local conditions.

Constituent	Soda-lime	Lead	Borosilicate
	(Ahmed, 1991)	(Ahmed, 1991)	(Phillips et al., 1972)
SiO2	70-73	60-70	60-80
Al2O3[a]	1.7-2.0	-	1-4
Fe2O3	0.06-0.24	-	-
Cr2O3[b]	0.1	-	-
CaO	9.1-9.8	1	-

MgO	1.1-1.7	-	-
BaO	0.14-0.18	-	-
Na_2O	13.8-14.4	7-10	45
K2O	0.55-0.68	7	-
PbO	-	15-25	-
B2O3	-	-	10-25

Table 2: Typical chemical composition of glass types

a Higher level for amber-colored glass.
b Only present in green glass.

Glasses have different shapes like Crushed glass particles are generally angular in the shape and may contain some elongated and flat particles. The quantity of flat and elongated particles and the degree of angularity depends on the degree of processing (crushing). Smaller particles, resulting from extra crushing, will exhibit somewhat less angularity and reduced quantities of flat and elongated particles. Uncontaminated or clean glass itself exhibits consistent properties; however, the properties of waste glass from Material Recovery Facilities (MRFs) are much more variable due to the presence of non-glass debris present in the waste stream. Table 3 gives some typical physical properties of waste glass collected from a number of MRF facilities (WSDTED, 1993).

Test	**Glass samples [a]**		**ASTM test method**
	Coarse	Fine	
Particle shape angularity	Angular	Angular	ASTM D2488
Flat (%)	20-30	1	
Flat/Elongated (%)	1-2	1	
Specific gravity [b]	1.96–2.41	2.49–2.52	ASTM D854[c] ASTM C127[c]
Permeability (cm/sec)	$\sim 2 \times 10^{-1}$	$\sim 6 \times 10^{-2}$	ASTM D2434

Table 3: Selected physical properties of waste glass

a Fine and Coarse glass samples represent minus 19mm (3/4 in) and minus 6.4mm (1/4 in) samples, respectively, collected from several MRF facilities unless otherwise indicated.
b Coarse specific gravity samples represent glass fraction greater than 4.75mm (No. 4 sieve); fine samples represent glass fraction less than 4.75mm (No. 4 sieve).
c ASTM D 854 and C127 procedures were used for coarse and fine fractions respectively.

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Standard sieve size	*Average % finer*
25.4mm (1 in)	100.0
12.7mm (1/2 in)	98.7
6.35mm (1/4 in)	86.0
3.18mm (1/8 in)	32.6
0.84mm (No. 20)	6.4
0.42mm (No. 40)	3.2
0.21mm (No. 80)	1.5
0.075mm (No. 200)	0.6

Table 4: Waste glass gradation results

4.2. Rubber tires

Tires takes a large landfill space. Disposal of large quantities of tires accordingly has many environmental and economical l implications. Scrap tire piles, which are growing each year, show two significant threats to the public: health hazard (the water held by the tires provides an ideal breeding ground for mosquitoes) and fire hazard (once set ablaze, they are almost impossible to silence). there are many types of rubber used in highway construction like Crumb rubber additive (CRA) is the generic term for the product from scrap tires used in asphalt products. Addition of crumb rubber additive to asphalt paving products can be divided into two basic processes. the dry process mixes CRA with the hot aggregate at the hot mix asphalt (HMA) facility before adding the asphalt cement to produce a rubber-modified HMA mixture, the wet process blends CRA with hot asphalt cement and allows the rubber and asphalt to fully react in mixing. figure 1 show the dry process mixes CRA with the hot aggregates at the hot mix asphalt (HMA).

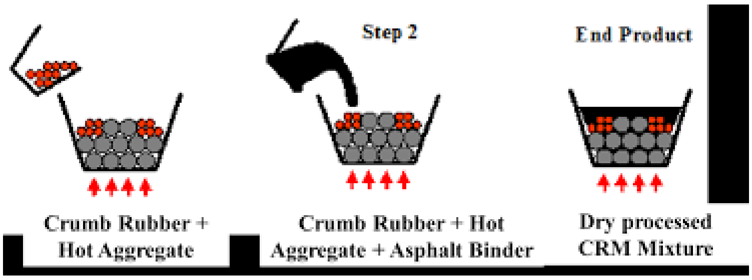

Figure 1: dry process mixes CRA with the hot aggregates at the hot mix asphalt

The four basic categories of asphalt paving products that use CRA include surface/interlayer treatments, rubber-modified HMA mixtures, crack/joint sealants and HMA mixtures with asphalt rubber binder. figure 2 dispose the surface recycling with crumb rubber tires.

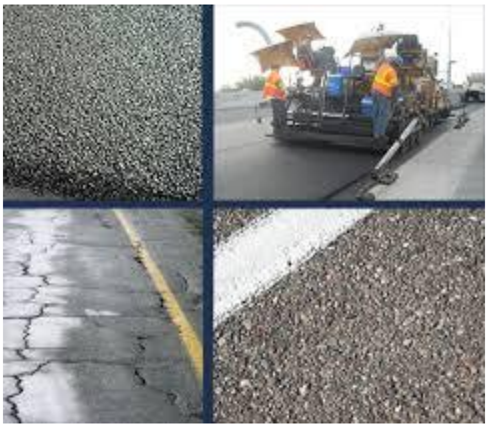

Figure 2: surface recycling with crumb rubber tires

4.3. Slag

Slag is one of the most natural products which is used in highway, rail ways and another part of engineering construction, which is principally divided into blast furnace slag and metallurgical slag. Figure 3 show these typed of slag. Slag has a great hardness, better adhesion and great stability properties, with these properties slag can use in highway construction for enhance of such properties of highways. Also it is now recognized as a valuable material with many uses in agriculture, environmental applications and in the construction industry. Air cooled course aggregate is used in concrete and asphalt mixes, fill material in embankments, road base material and as treatments for the improvement of soils. Ground Granulated Blast Furnace Slag (GGBFS) has a positive effect on the flexural and compressive strength of concrete. Expanded slag has low density allowing for good mechanical binding with hydraulic cement paste. Bulk density, particle size, porosity, water holding capacity and surface area makes it suitable for use as an adsorbent.

Figure 3: two main types of slag: blast furnace and metallurgical slags

5. Reclaimed Asphalt Pavement

The amount of utilizing reclaimed asphalt pavement (RAP) in hot mix asphalt (HMA) and base material in Ontario has been reported to be as low as 8% of the total recycled material used between 2004 and 2006. The specification of RAP varies from one source to another according to the properties and type of binder content, aggregates material and binder stiffness of the scarified pavement. The concentration of RAP in the new asphalt mixture is considered pivotal factor influencing performance of HMA. It has been reported that the performance of an asphalt pavement made of new material would be as equally satisfying as that composed of a low to intermediate rate of 25% RAP. Technically, rectification of the binder grade in the asphalt mixture, especially in the low temperature grade, does not need much concern, when RAP is used in less than 15% of the total weight of the mixtures. It has been reported that the performance of a new asphalt pavement would be as equally acceptable as that composed of a low to intermediate rate of 25% RAP. The implications of using a rate of more than 20% of RAP on the grade of binder is significantly higher than that when the rate is in the low range (< 20%). However, when a combination of an average rate of 20% RAP along with 3% recycled asphalt shingles (RAS) is used, low temperature grade of asphalt cement goes up by 6ºC and a reduction in the low temperature performance grade of asphalt cement was suggested. The maximum permitted rate of RAP in HMA application as per MTO specification requirements is 30%. It is believed that higher added amount of RAP in HMA application is the reasons of premature road failure which needs to be examined by routine testing on supplied HMA by contactors.

Conclusion

Use of waste materials as a construction material can effect on the environment. More production equals more waste; more waste creates environmental concerns of poisonous threat. An economical viable solution to this problem should include utilization of waste materials for construction purpose, which in turn minimize the heavy burden on the nation's landfills. Recycling of waste construction materials saves energy, natural resources, reduces solid waste, reduces air and water pollutants and reduces greenhouse gases.

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