WASTE PHOSPHATE IN HOT MIX ASPHALTS TO IMPROVE RUTTING RESISTANCE

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ABSTRACT

Fillers have an important role in rutting phenomenon on highways. Investigating the rutting behavior of hot mix asphalts containing phosphate waste filler is the purpose of this research. The results compare with mixtures that contain lime stone filler (standard mixtures). The Marshall characteristics were improved for mixtures which contain waste phosphate comparing to standard mixtures. The Wheel tracking machine (WTM) results revealed that phosphate waste filler improved the rutting resistance 1.6 times as compared to the standard mixture.

Keywords: Waste phosphate, Hot mix asphalt, Rutting resistance, Deformation, Wheel Track

1-INTRODUCTION

Rutting is a major distress form found in asphalt pavements, especially when the ambient temperature is high as in a hot tropical climate or during the summer months of temperate countries. Rutting is caused by the accumulation of irreversible or permanent deformation in all pavement layers under the action of repeated traffic loading. Among the contributions of rut depth by the various pavement layers, the cumulative permanent deformation in the surface course of asphalt pavement is known to be responsible for a major portion of the final rut depth measured on the pavement surface. Therefore rutting resistance of a paving asphalt mixture is one of the important considerations in standard procedures for asphalt mix design ~Asphalt Institute 1997; SHRP 1994.

Large amount of phosphate rocks are available in Iran. Large proportions of mined phosphate are waste and have a direct negative impact on the environment. Consequently, this research focuses on using a kind of phosphate waste as fillers in a typical wearing course mixture. Such phosphate waste will include the 4.5-mm reject. The limestone filler will be incorporated in a typical wearing course mixture and will be considered in the analysis as a control mixture for comparison purposes. In this research, the optimum binder contents for the mixtures considered will be calculated using the Marshall mix design (ASTM 1974). In addition to investigating the Marshall characteristics of the various mixtures, the wheel tracking machine (WTM) will be used to evaluate mixture resistance to deformation (Specifications 1991). The following sections will consider the properties of the phosphate waste that was used in this research, test methods and their results, and conclusions.

2-BACK GROUND

The name Phosphorus is derived the Greek word "Phosphoros" that meaning "light bearer & light bearing & bringer of light "which was the ancient name for the planet Venus. Phosphorus is a White, black and brownish-red nonmetal, with the symbol of P, atomic number 15, atomic weight 30.973, specific weight 1.82 gr/cm3, boiling point 280ºC and melting point 44.3ºC. Its abundance (weight) is 0.13% in the crust. Phosphate is located in periodic table group 15 (VA) and the alteration period 3 and nonmetal Series. White phosphorus (P4) is a lustrous, soft , waxy, flammable, solid. Brownish-red phosphorus is powdery and usually non-flammable. A multivalent nonmetal of the nitrogen group, phosphorus is commonly found in inorganic phosphate rocks and in all living cells. Due to its high reactivity, it is never found as a free element in nature. It emits a faint glow upon exposure to oxygen (hence its name, Latin for 'morning star', from Greek words meaning 'light' and 'bring'), occurs in several allotropic forms, and is an essential element for living organisms. Common phosphorus forms a waxy white solid that has a characteristic disagreeable smell similar to that of garlic. Pure forms of the element are colorless and transparent. This nonmetal is not soluble in water, but it is soluble in carbon disulfide. Pure phosphorus ignites spontaneously in air and burns to phosphorus pent oxide. Phosphorus exists in three allotropic forms: white (or yellow), red, and black (or violet). Other allotropic forms may exist. The most common are red and white phosphorus, both of which consist of networks of tetrahedral arranged groups of four phosphorus atoms. Red phosphorus is comparatively stable and sublimes at a vapor pressure of 1 atm at 170 °C but burns from impact or frictional heating. A black phosphorus allotrope exists which has a structure similar to graphite – the atoms are arranged in hexagonal sheet layers and will conduct electricity.

The most important commercial use of phosphorus is in the production of fertilizers. It is also widely used in explosives, friction matches, fireworks, pesticides, toothpaste, and detergents. Concentrated phosphoric acids, which can consist of 70% to 75% P2O5 are very important to agriculture and farm production in the form of fertilizers. Global demand for fertilizers has led to large increases in phosphate (PO43) production in the second half of the 20th century. Other uses; Phosphates are utilized in the making of special glasses that are used for sodium lamps. Bone-ash, calcium phosphate, is used in the production of fine china and to make mono-calcium phosphate which is employed in baking powder. This element is also an important component in steel production, in the making of phosphor bronze, and in many other related products. Trisodium phosphate is widely used in cleaning agents to soften water and for preventing pipe/boiler tube corrosion.

White phosphorus is used in military applications as incendiary bombs, for smoke-screening as smoke pots and smoke bombs, and in tracer ammunition. Red phosphorus is essential for manufacturing matchbook strikers, flares, and, most notoriously, methamphetamine. In trace amounts, phosphorus is used as a dopant for N-type semiconductors. Miscellaneous uses; used in the making of safety matches, pyrotechnics, pesticides, toothpaste, detergents, etc. The following uses for phosphorus are gathered from a number of sources as well as from anecdotal comments. I'd be delighted to receive corrections as well as additional referenced uses (please use the feedback mechanism to add uses. phosphates are used in the production of special glasses, such as those used for sodium lamps bone-ash, calcium phosphate, is used to produce fine chinaware and to produce monocalcium phosphate used in baking powder important in the production of steels, phosphor bronze, and many other products Na3PO4 is important as a cleaning agent, as a water softener, and for preventing boiler scale and corrosion of pipes and boiler tubes pesticides.

The phosphate industry currently deposits approximately 60% of waste in ponds and or below ground level. The holding ponds are costly and not environmentally aesthetic. There also has been a great demand from Environmentalists that these wastes be deposited below ground level for aesthetic reasons. This is of particular concern as the volume of waste produced from mining and beneficiation of phosphate rock exceeds the mined out volume. To date, no proven large-scale system has been developed that can be considered either environmentally sound or economically viable (Austin 1984). It is important to note that uranium is present in all phosphate rocks. Florida rock contains the most uranium, and rock from the western states of the United States contains the least. Uranium is present as a trace constituent, but because of the high value placed on this material, it is becoming very important to recover it. The energy value of extracted uranium, which is converted to yellow cake U3O8, is 10 times greater than the energy required to produce it. This could make the phosphate industry a net producer of energy. The uranium in Iran phosphate rock is very low compared with the phosphates of other countries.

Phosphate rocks have a wide range of P2O5, and the economical phosphate rock is the type that contains >50% tricalcium phosphate content (TPC). Otherwise, beneficiation is required to raise the P2O5 content. Also, the phosphate that has <50% TPC after beneficiation is not considered economical. It is then termed phosphate waste. This was forms approximately 20–30% of the total production of phosphate. This waste is left in the mines and on the surface, and it considerably affects the environment and, obviously, agricultural lands.

3-MATERIALS AND SAMPLE PREPARATION

Crushed stones of limestone were used for coarse and fine aggregates. Phosphate Waste that used as filler was obtained from Shemshak mine about 45 km distance in north of Tehran. The phosphate waste was all crushed into fines passing the 200 mm sieve. Table 1 shows Chemical Components of Phosphate Wastes which used in this research. Limestone filler was used for standard mixtures. Two similar aggregate gradations were considered for the analysis. Table 2 shows the aggregate gradation for sample fabrication. For Marshall specimens, 70 penetration binder were considered for each aggregate gradation. Three specimens were fabricated at each binder content. The Marshall mix design procedure as specified in ASTM D1559 was used in this study. Laboratory mixing and compaction temperature for all mixtures were selected according to viscosity criteria.

To measure the ability of mixtures to resist rutting, the apparatus was the WTM. The wheel tracking machine used in this study was modified from a three-wheel tracking machine commonly used in Iran Science and Technology University. The machine allowed control of the following test parameters: test temperature, wheel speed, and wheel load. The mixtures were prepared at the optimum binder content according to Marshall mix design and compacted in perforated metal molds under standard conditions. In this test, the wheels travel with a reciprocating motion of 60 cycles/min. The criterion that is adopted to measure the ability of the mixtures to resist rutting is the depth of penetration of the wheels into the specimen under 6000 cycles. The temperature of the bath where the specimens were located was set at 50 ºC.

Table 1- Chemical Components of Used Phosphate Waste

Phosphate Waste(4.5 mm Reject)	Component
20.9	P2O5
31.2	CaO
<0.1	SiO2
0.6	Fe2O3

Table 2- Used aggregate gradation

Percentage Passing (%)	Sieve Size
100	3/4 "
95	1/2"
59	No 4
43	No 8
13	No 50
6	No 200

4-TEST RESULTS AND DISCUSSION

Table 3 shows the optimum binder contents (OBCs) for all mixtures with their corresponding Marshall characteristics at the OBCs. The mixtures containing the Waste Phosphate filler have higher OBC than Standard mixtures. The table further shows that at their OBCs, the mixtures containing the phosphate waste exhibit considerably higher stabilities and approximately similar flow values. The high stability values for the waste phosphate filler could be attributed to the fact that the hardness of the phosphate particles on Mohs scale are more than lime stone particles. This is in addition to the higher densities obtained with these fillers compared to the standard mixture. Unfortunately, the Marshall stability and Marshall flow alone cannot be used reliably to indicate mixture resistance to permanent deformation. The Marshall flow is a measure of the permanent strain at failure and therefore cannot be interpreted as a measure for resistance to deformation. Lees (1987) indicated that the term ‘‘flow’’ used by Marshall is an unfortunate one because the high flow value does not necessarily mean that there is a high tendency to flow or deform under load. Lees (1987) claimed that many institutions worldwide have misused the terms ‘‘flow’’ and ‘‘stability,’’ which ultimately led these institutions to reject mixtures that should have been accepted and to accept mixtures that should have been rejected. Uge and Van de Loo (1974) and Hills (1980) criticized the Marshall test method for its poor reproducibility. Table 4 shows that the mixtures containing waste phosphate fillers sustained less penetration of the wheels than the standard mixture. On the other hand, The mixture containing waste phosphate filler provides better rutting resistance than the mixture containing lime stone filler. This could be attributed to the fact that the hardness of the waste phosphate filler is higher than the lime stone filler. Mixture containing waste phosphate filler showed on average 1.6 times more resistance to rutting than the standard mixture.

Figures 1 and 2 show respectively the apparatus of counting cycles in wheel track machine with temperature controller and the sample that has been made by waste phosphate filler and loaded about 6000 cycles.

Table 3- Comparison of Marshall Characteristics Mixtures at Corresponding OBCs

Air Voids at OBC (%)	Flow at OBC (mm)	Stability at OBC (KN)	Specific Gravity at OBC	OBC	Filler type
4.0	3.40	12.2	2.30	5.6	Lime Stone
3.6	3.35	15.1	2.38	5.8	Waste Phosphate

Table 4- Wheel Tracking Test Results for Mixtures

Wheel Penetration (mm)	Filler Type
3.28	Lime Stone
2.04	Waste Phosphate

Figure 1- Cycles counter and temperature controller in wheel track machine

Figure 2- Waste phosphate filler sample under 6000 cycles loading

5-CONCLUSIONS

The following conclusions are based on the properties of the materials used and according to the test conditions adopted in this research

1) The Marshall characteristics of the mixtures containing waste phosphate indicated higher stability and flow values than those obtained with the standard mixture

2) 2) The incorporation waste phosphate fillers used in this research considerably improved the ability ofv mixtures to resist deformation as measured by in this research.

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