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Feasibility of mine waste in sugar production plants (hydrated lime) as a filler to increase resistance to rutting and improve the adverse effects of moisture and frost in hot asphalt mixtures

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Abstract: *Rutting of pavement's Asphalt may cause serious problems with increased traffic of heavy vehicles, especially in tropical regions. Increased resistance of asphalt mixtures has always been an important issue in improving the efficiency of road pavement. Various methods for increasing the resistance of asphalt mixtures are presented. In this study, a new material is used to increase the resistance that was not considered before. In sugar producing factories, used lime of the production process remains as waste and abandoned in environment; under the influence of climatic factors (wind, flood) it is transferred to the surrounding environment contaminating agricultural lands and gardens as well as the groundwater. Therefore, efficient use of it (lime waste) as a valuable product in the economic cycle is profitable, thus; the first option in efficiency can be the manufacturing of hot asphalt industry from some additives such as hydrated lime as filler. The possibility of using hydrated waste lime produced in sugar factories instead of the current consumption is the objective of this study. The plan's success will play an important role in the creation of added value. Several field trials were conducted by adding varying amounts of the material as filler in asphalt and product's quality indicators were measured. The results indicate the possibility of replacing the material instead of current ones.*
Keywords: *hot Asphalt mixtures, hydrated lime, pavement, rutting*

1. INTRODUCTION

Asphalt pavements is damaged dude to the passage of time, the effects of traffic loads and weather conditions. One of the most common damages is the rutting of asphalt pavements. Rutting refers to permanent deformation as a groove in the direction of vehicles' wheels parallel to the longitudinal axis of the path (Kavoosi and Bakhtiari, 2013). Recently, attempts have been made to modify the mechanical properties of asphalt mixtures and reduce their rutting; one of the most suitable solutions is to modify asphalt mixtures by additives.

Sugar factories use alkalis such as hydrated lime as part of their production process to increase the PH of environment and discoloration. The substances used in the production process, are filtered and exit the factory as wastes (Figure 1). Unprincipled Depot around factories and mass production of these materials creates inappropriate landscapes in nature. In addition, due to its continuous release into the surrounding environment by local winds and waters, increase Basicity in arable soils of surrounding area even km away from the factory.

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Figure 1. lime waste discharging on the outskirts of the city

There are 32 sugar factory in Iran that include: Ghand- e- Abkooh, Urmia, Eslam Abad gharb, Ghand –e- Isfahan, Eghlid- e – Fars, Ahvaz Bardsir, Bistoun, Ghand – e- pars, Piran shahr, Torbat- e- jam, Tarbat- e- Heidarieh, Fariman Joubin, Sabzevar, Chenaran, Chahar Mahal Bakhtiari, Khoy Tabriz, Shahzank Arak, Shahroud, Shirvan, Shirin Mashad, Fasa, Ghazvin, Ghand – e- Ghahestan (Asadiyeh), Lorestan, Marvdasht Fars, Parsabad Moghan, Miando ab, Naghadeh, Naghsh-e- jahan Isfahan, Neishabour, Hamedan.
Ghahestan sugar factory was established in 1961 (Figure 2). Release and discharge of lime by Ghahestan sugar factory (Asadiyeh) caused environmental damage and negative impact on the residential context, rivers and urban areas. According to the digits produced by this unit, a total of 3500000 tons of sugar beet as raw material has been entered to this factory for the preparation of Sugar from the initially set up of this unit till now. Based on the factor of 10 per cent use of lime, close to 350,000 tons of hydrated lime as waste is produced production around the city of Asadiyeh. It should be noted that Ghahestan sugar co works with a minimum capacity when compared with other sugar factories of Iran. Larger factories release hydrated lime than twenty times more than the mentioned factory.

Figure 2. Images of Ghahestan sugar factory

2. METHODOLOGY

Hot asphalt, is a mixture of crushed and graded aggregates and fillers heated in asphalt factory, mixed with hot bitumen at a given temperature, and is crushed and then used as a hot product in roads, streets, airports, docks, terminals etc. High durability, uniform production, controlled temperature, humidity materials, fast

preparation are the benefits of hot asphalt being consumed without any limit on the roads, streets, airports, docks, terminals, and parking lots etc. Qualitative characteristics expected from asphalt behavior depend on the different climatic conditions of each region. Therefore, raw material of asphalt in each of the hot and dry, hot and humid and cold weather will be different. So many factors affect the quality of asphalt that can be mentioned in the following: Type of asphalt, aggregate, filler types and application requirements etc. In this study, the role of filler in asphalt heating quality will be discussed in particular. The properties of the filler used in asphalt mixture and the used amount in the mixture phase have a great influence on the final properties of the asphalt. In accordance with ASTM and ASHTO standards, filler is described as mineral materials with a maximum size of 600 micron that at least 70% of it pass through sieve no. 200.

2.1 The role of filler in the quality of asphalt

Increased life of pavement, increased resistance to the effects of water, increased power of bearing, reduced relative deformation, increased impact resistance, increased compressive and shear strength and reduced fragility are some of the characteristics of filler in asphalt quality.

Filler improves the adhesion of bitumen to aggregate with two mechanisms:

A. Mechanically

Increased viscosity and hardness of bitumen (high viscosity, higher adhesion with aggregates)

The increase in the adhesion of bitumen to aggregates depending on the material and dimensions of filler particles

B. Physically and chemically

Limestone fillers provide an effective response on the contact level of bitumen and aggregates. These actions will improve the adhesion of asphalt to aggregates.

Increased adhesion of asphalt to aggregates improves the performance and durability of asphalt mixtures. Chemical composition, geometrical shape, texture and adsorption, adhesion and other properties of filler have an important role in asphalt mixtures and bitumen and filler's paste system.

2.2 Limestone filler to prevent stripping of aggregates of asphalt mixture

The main reason for the stripping is separated into two mechanisms of adhesion failure and cohesion failure. In the absence of water, adhesion of bitumen to aggregates easy, but in the presence of water, aggregates are more likely to be soaked in water, so water weakens or disintegrates the connection (adhesion) of aggregate-bitumen (Ameri et al. , 2014). Loss of cohesion occurs due to the softening of the bitumen in asphalt mixes. In this case, the failure of the bond between components of asphalt from the pavement surface is started. Then aggregate is separated from pavement surface and water infiltration is intensified into the pavement surface. In some cases, the effect of these two mechanisms in pavements results in early stripping of asphalt mixtures. Environmental conditions, type and the use of asphalt mixes, stone materials of poor quality, high viscosity and the type of bitumen, the presence of dust in the aggregates, inappropriate operational actions and insufficient density of asphalt mixtures, the percentage of large voids, heavy traffic load, etc. result in stripping. However, the main cause of this phenomenon, is the pore water pressure in saturated asphalt mixtures due to traffic load, and long-term presence of water in the asphalt layers. Stripping of asphalt mixtures as a result of moisture can be largely controlled and reduced by the selection of good quality material, suitable mix design, increased thickness of the asphalt, the use of anti-stripping additives, detailed technical implementation and monitoring, appropriate density and optimal drainage. So far, some additives such as hydrated lime, sulfur, antioxidants, liquid anti stripping materials, rubbers, black carbon and different types of polymer have been successfully used to reduce stripping.

2.3 contributing factors in the Occurrence of stripping

Specifications of aggregates and their chemical and physical properties such as construction materials, porosity of aggregates, water absorption ability, physical characteristics of the filler and the fineness of the factors affect the sensitivity of asphalt mix (Sengoz and Agar, 2007), (Ghaffarpour, 2008). Silica aggregates

(with a Negative-electronegative surface charge) known as hydrophilic aggregate, more than the limestone aggregates (positive- electropositive surface charge), called hydrophobic aggregates, experience stripping. Selection of the type and quantity of bitumen is done by considering the weather conditions, traffic, building materials, the type and thickness of the pavement and its implementation. The type of bitumen, the process of refining, the viscosity of the bitumen, its thickness and many of the characteristics of bitumen influence sensitivity of asphalt toward stripping but its effect is less important than the type of aggregate. To create the highest-level contact between the bitumen and aggregates, bitumen viscosity must be appropriate to aggregate the well cover. To create the highest-level of contact between the bitumen and the aggregates, the bitumen's viscosity must be appropriate to cover the aggregate well. The Ability of melted bitumen to establish contact with the aggregate's surface, is coverage power of stone materials and is dependent on the viscosity of bitumen. The less is viscosity of the bitumen, the more is its coverage capability. On the other hand, the greater is the viscosity of the used bitumen in asphalt mixture, the greater is the resistance to stripping (Maupin, 2002). The presence of dust on the aggregates, empty spaces on the asphalt mix, executive cracks and insufficient density have a significant impact on the occurrence of stripping as well.

2.4 The mechanism of reducing the moisture sensitivity

Since the phenomenon of stripping depends on the adhesion of bitumen and aggregate to repair the damages, we have to improve the adhesion properties of bitumen and aggregate. To improve and strengthen the connections between bitumen and aggregates, additives can be used as filler or liquid. There are many additives reducing moisture sensitivity in asphalt mixtures; hydrated lime is one of the widely used ones. Hydrated lime also can speed up hardening of asphalt because of its oxidizing capability. Other additives which reduce stripping are; liquid additives (amines and diamines), polymeric materials, cement etc. (Ali Nasab, et al., 2014). There are several theories In terms of the reasons for the effects of lime on asphalt mixture: Lime improves the connection between calcium and silica in the aggregates. Lime alkalinity leads to better adhesion with the acidic bitumen. In aggregate covered with clay, there is ion exchange and pozzolanic reaction between the oxidation percentage of clay and calcium sulfate in lime and silicate. It is thought that the lime severely reacts with carboxylic acid of tar so fewer acids are absorbed by the aggregates resulting in the greater adhesion between bitumen and aggregate's level. In addition, lime changes chemical properties and polarity of the aggregate's level and creates a stronger bond with bitumen. Studies have shown that the amount of hydrated lime required to improve the performance of asphalt mixtures against moisture is between 1 to 2 percent of the weight of the stone materials. Some mixes need more (2.5 percent) lime to achieve the desired characteristics. The amount of fine grain aggregate is more because of the increased surface area of aggregates, asphalt mix to a greater amount of lime to improve resistance is required. The more is the amount of fine aggregate in granularity, the more lime is required to improve resistance of asphalt mix because surface area of aggregates the increases. Studies have shown that the water has a high PH level in aggregates and therefore the liquid anti-stripping materials at the surface are soluble with a high PH water. Hydrated lime creates a strong connection between bitumen and aggregates which is resistance to stripping at all PH levels. In this study, we attempted to take advantage of hydrated lime being the waste of aforementioned factories as filler in hot asphalt production process.

3. PILOT PRODUCTION OF ASPHALT USING WASTE FILLER AND QUALITY CONTROL TESTING

In order to investigate the possibility of using waste hydrated lime powder from the sugar industry in the production of asphalt, some experiments were designed and tested. First, the correct sampling was done from the existing depot. Then two asphalts (one with lime filler and the other without the calcareous lime filler) were produced in parallel and used as warm covers in the same conditions. After that, Samples were evaluated by the laboratory of quality control sampling. The results are compared in Table 2. The Process is as follows.

3.1 Sampling

Sampling is very important in any tests. Sampling must be done such that it represents the entire depot behavior. Due to the large sample size, it was needed for sampling to be done systematically. For this purpose, different parts of depot by loaders and trucks were mixed together in one convenient place. Manual sampling was done from different parts of the depot which was sent to specialized laboratories to conduct chemistry and physics testing. Also a part of the original sample was transported by truck to the asphalt production plant and added as a filler to the system. The results were compared with control samples.

3.2 Chemical analysis

Representative sample was sent to magnesium oxide production plant for chemical analysis and the following results were obtained. (Table 1)

Table 1. Chemical analysis of waste hydrated lime

%L.O.I.	%MgO	%CaO
37.3	4.4	**37.72**
%SiO2	**%CaO**	**%Al2o3**
46.25	37.72	**6.83**

According to laboratory results, samples are calcinated at 1100 °. High levels of silica in the samples, is due to the mixing of waste lime with the soil at the plant resulted from washing raw materials in factory.
The results of Sieving analysis are presented in Table 2.

Table 2. Sieve analysis of waste hydrated lime samples

Authorized frequency	The number of seiving
5	30
7	50
88	200

The sieve analysis reveals that the sample results are consistent with the relevant standard. There are no restrictions in terms of compliance with the relevant laws.

3.3 Tests determining the quality of hot asphalt by two mechanisms (using limestone filler and without it)

Finally, to determine the quality of hot asphalt – due to the use of limestone fillers - some tests were performed and their results are offered in two states of asphalt without the limestone filler and with limestone filler in Table 3.

Table 3. the Comparison of test results with two asphalt samples

Description of experiment	The sample of asphalt without lime filler	The sample of asphalt without lime filler
The percentage of bitumen to asphalt	4.38	4.17
Strength (kg)	1390	1659
Marshall sample density (cc / g)	2.383	2.371
Softness (mm)	2.7	2.4
One side fracture (percent)	--	--
Two sides fracture	98	99
Temperature of asphalt road (C)	145	140
Temperature of Asphalt ambient	21	14
The empty space of Marshall sample (percent)	5	**5.7**
Porous spaces of materials (percent)	14.7	14.9
empty space filled with bitumen (percent)	65.8	61.2
Materials real gravity (cc / g)	2.670	2.669

4. SUMMARY AND CONCLUSION

Quality control testing results clearly indicate that the quality of produced asphalt using the tested filler shows ideal conditions. The use of waste lime of the factory (hydrated lime) increases parameters such as Marshall resistance, resulting in resistance of asphalt pavement against harmful effects such as rutting and moisture sensitivity. In addition, the use and disposal of these wastes will end a lot of environmental pollution related to their release in nature. This is a major step in the field of environment. The researchers are planning to specifically examine environmental conditions using hydrated lime in asphalt industry and other areas of its use in further studies.

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