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Application of Iron Slag at Different Pavement Layers

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Abstract

Reusing waste material in the past decade has got too importance and the reason is emphasizing on environment laws and reducing the pollution of industrial garbage. Steel-making operations has faced with this problem because of producing a large amount of waste material during production which in the case of steel industries ability to recover and using this products, these products create many problems in terms of pollution for environment with regard to their high production volume including slag, dust, sludge, shell sheets and oxide layers in which slag has got the most importance than others because of high production rate. Nowadays, broad research has performed in the world to recycling these side products which have resulted to solutions to recover them. In Iran with regard to the increasing of steel and slag production, research on them and appropriate solutions to use in different applications and reducing environmental pollution seems necessary. This paper addresses the investigation of iron slag at different pavement layers and the influences like frictional resistance, track disruption and bearing strength that it produces.

Key words: Iron slag, frictional resistance, track disruption.

1 Introduction

Slag is a molten material which is created due to interaction of molten materials, limestone, fuel and existing oxide impurities in metal. During these interactions, the impurities that mustn't be in cast iron will be separated from pig iron. Steel slag (iron) is side product during production and steel manufacturing. This product is created in one of the three types, fire furnace, basic-oxygen furnace or electric arc furnace. This product is different from tall furnace slag which is a product during iron making process production in terms of chemical properties [3]. The produced slag from steel making furnaces is usually cooled by free air and a solid stony material will be created which is similar with basalt in appearance. Basic-oxygen steel slag and electric arc furnace slag both have similar chemical and physical properties. Chemical composition of blast furnace slags changes with regard to steel making method and the quality of produced steel [4].

The positive characteristics of blast furnace include [4]:

1- Resistance and high stability against impact
2- The excellent angular shape of aggregate which creates appropriate internal friction angle
3- High resistance against load, pressure and abrasion
4- High sliding resistance because of frictional strength among aggregates
5- Bitumen absorption percentage due to high alkali property

The mean of physical properties of blast furnace slags, tall furnace slags and basalt stone are shown in Table 1 [4].

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2 Application of Blast Furnace Slag in Road Surface

Surface layer in road pavement is a layer of high-grade gender and rather with high strength that is located directly in contact with vehicles. Surface layer in the high traffic roads is made by high grade materials such as asphalt concrete or cement concrete.

Table 1: Average of physical properties

Specifications	Iron slag		Tall furnace slag	Basalt stone
	BOS Slag	EAF Slag		
Density of materials (Kg/m^3)	3400	3400	2600-2500	2850
Actual density (Kg/m^3)	1700	1700	1300-1200	1520
Resistance in dry condition (KN)	250	275	100-85	350
Resistance in wet conditions (KN)	230	240	90-65	-
Losanjeles resistance	13-15	13-15	43-37	13
sliding resistance	58	62	50	55-50
Relent	15	20	-	12
Impact resistant	12	14	-	12
Ductility factor	11	6	-	28
Water absorb	0.9	0.5	-	1.9
pH	11	11	-	0.9

The improvement of surface performance in different climate conditions and long-time heavy traffic has been the main purpose of pavement designers and road-construction engineers. Hence to improve the status of roads surface in terms of friction and strength increase against other destructions, various materials have been investigated in

laboratories that blast furnace slags have been also among them and are utilized in asphalt surface and/or concrete surface [5, 6]. Using slag in surfaces causes the increase of sliding strength and also increasing strength against surface rutting.

2.1 Skid resistance and friction properties

Resistance against slippery is defined as a reaction force resists against vehicle sliding and prevents gliding of tires on pavement level [7]. The aggregates that are used in asphalt production have appropriate friction coefficient in the first use of road surfaces but during time and with the increase of vehicles traffic becomes smooth and their roughness will be reduced. Some of reports indicate disappearing 50% of initial roughness in the first two years of pavement service. Hence using aggregates that have resistance and rather high roughness has had special importance in terms of roads safety. Physical properties and surface texture of steel slag creates a friction coefficient at surface layer that is usually more than natural aggregates [8]. The individual composition of blast furnace slag which is constituted by hard small structure causes the appearing of pavement surface cover with proper long-time skid resistance that usually is not the case in natural aggregates. [8]

Young Gi et al. performed an experiment on a component of one constructed road from blast furnace slag in China under standard conditions to assess pavements asphalt surface skid strength and they realized that the performance of steel slag in terms of hardness and also having roughness coefficient is too great. Table 2 shows the experimental results [9].

Table 2: road experiment performance

Experiment	Period of service			
	6 month	12 month	18 month	24 month
The specific gravity of the core samples (gr/cm^3)	2.511	2.520	2.524	2.525
Abrasion and coefficient of friction (BPN)	62	60	56	55
Depth textures surface (mm)	1.2	0.9	0.8	0.8

2.2 Resistance against rutting

Rutting is often refers to permanent deformation that happen in the path of vehicle wheels passing and parallel to road longitudinal direction. The iteration of loading from heavy vehicle passing and lack necessary pavement bearing strength results in the creation of this kind of destruction. Such a phenomenon happens often in tropical areas. It is also possible that rutting in the path of wheels passing is together with bump near to track. Regardless of aggregate type and its processing method, aggregates in warm asphalt admixture must create enough shear strength to resist against frequent traffic pressure. When additional load is applied on aggregate, a shear plane is developed in aggregates particles and shear than to each other causes deformation or rutting (figure 1-a). Rutting results happens when shear tensions is more than aggregate shear resistance along to this shear plane. (Figure 1-b) [5, 8].

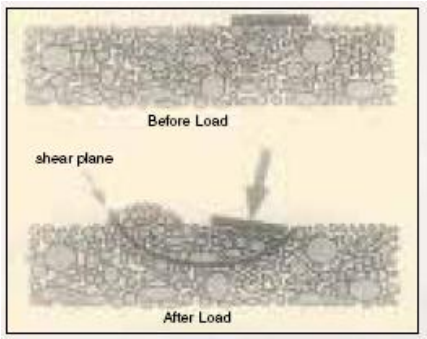

Figure 1-a: aggregates shear than each other

Figure 1-b: rutting in the effect of applying additional load.

Shear resistance at asphalt admixtures depends on two parameters: The internal friction angle of stony material and also admixture adhering coefficient. But because slag materials have cubic shape and their rough texture, the prepared admixtures from these materials have more resistance than natural flat and round aggregates. [8]

2.3 Stone matrix asphalt

Asphalt pavement has different types that one of them is asphalt with open gradation. Blast furnace slag has broad application in this kind of pavement.

Stone matrix asphalt is European pavement technology that is designed to prevent from crushing and sliding from heavy traffic pressure. This technology has focused on preparing durable pavements that have lower sensitivity to thermal cracks and creates one friction layer to reduce water fracture phenomenon (hydroplaning).

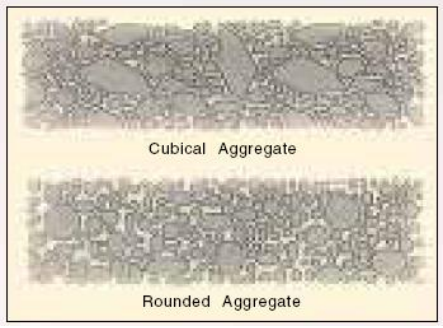

Figure 2: The cubic and round-sides shape of slag aggregates.

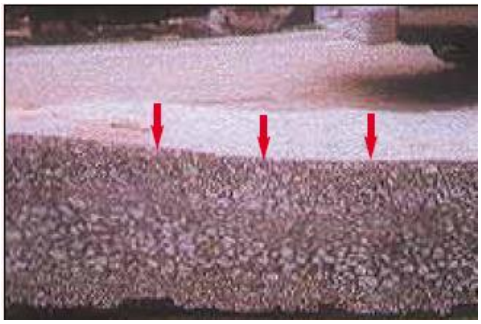
Figure 3: Deformation of pavement before substitution with SMA admixture along with iron slag.

Stone matrix asphalt is from coarse aggregate and includes open gradation. In this matrix network, contrary to superpave pavement samples, the aggregates with rough texture are as close and sticking together contact. This issue causes increasing appropriate internal friction angle and high shear resistance. Tar in stone matrix asphalt is typically from polymer type between 5-8 percent. Lower fine aggregates are used in this admixture to ensure from particle to particle contact and increasing the percent of aggregate empty space. Using steel slag in stone matrix asphalt has shown many successes. Because of steel slag stability, aggregates contact is not vanished during manufacturing. Moreover, aggregate steel slag is perfect for the creation of friction at pavement surface. The thermal characteristics of steel slags have many advantages to protect against different temperatures.

3 Application of Iron Slag at Base and Sub-Base Layer

Since slags are materials with sharp sides and similar to crashed materials so they can be used as appropriate aggregates in base and sub-base of roads. Steel slag aggregates usually are used with the distances of 100km from steel-making location, so the application and availability of slag is an important problem and its utilizing is not restricted in many sections. Where steel slag is available, its utilizing in basic applications can be considered and not only their gender, but also their type must be closely assessed. The chemical property of steel slag can be different between various mines and it is too important that the properties of these materials will be examined during using them. The chemical composition of some steel slags causes inappropriate expansion surfaces. Since mid-twentieth century, steel slags are used as aggregate in many construction industries. The main use of slags are for embankments, roads, rail-road upstream, building materials, landscaping, cement replacement, cement and soil stabilization. Madar et al. performed a research on steel slag application in road construction. Chemical-physical characteristics of steel slags in comparison to existing natural aggregate demonstrated the suitability of air-slacked steel slag to use in the base and sub-base of pavement. Pavement designing based on analytic methods shows clearly that using established layers with slag in base and sub-base layers results in the small improvement of tensile strain at tar sub-mix and also low compressive tension at above sub-grid. This improvement causes the reduction of fraction and wheel path depression at pavement and finally the increase of pavement life-time. Haldi studied the different characteristics of slag including density and the amount of water absorption, mechanical strength, friction properties and expansion and he concluded that steel slag can be an appropriate aggregate for embankments, base and sub-base, and the upstream of rail-road etc. [8, 10].


Figure 4: using slag in base and sub-base layer

Industrial countries prefer using steel slag in bituminous pavement because of the extraordinary stability, long life-time and high friction strength which provides a safe surface. The operation of road construction has shown that slag can be mixed simply and if compressed correctly, a major difference will be obtained rather to common materials. Also it has demonstrated proper strength characterization, volume stability, durability and free draining. Also it has a thorough cubic angular shape and with high internal friction angle to natural stones and is appropriate as asphalt mixture aggregate; contrary to natural stones, slag tends to preserve high friction resistance than time, climate factors and abrasion against traffic. Gradated clean slag satisfies structural and physical necessities of all road layers in general. Steel slag specially is used as the material of road shoulder without pavement. The cement properties of steel slag in road shoulder results to a durable, stable and hard road shoulder which is too more durable than the shoulders of the roads that are made from other aggregates [8, 10].

Researches on slag in Ahvaz yielded following results [11].

1. In the areas that sub-grid soils or underside layers are from clay, mixing them slag with these soils amends their properties and can be used in streets and roads embankment.
2. For bypass roads and streets with low traffic, the admixture of slag with local soil and limestone can be used as sub-base layer and the ratios of materials is 50% slag and 40% soil and 10% limestone.
3. The use of slag or admixture of slag and soil or slag, soil and limestone is possible for roads and streets with low traffic with ratios of 50% slag, 40% soil and 10% limestone [11].

3.1 Application of blast furnace slag as ballast

Since 1900, some of slags from melting metals as ballast have been used in rail-road lines. In the lines in which trains move with high velocity, the aggregates of slags are utilized as sub-ballast and coarser particles in ballast construction. Slag ballasts due to high porosity have appropriate draining property. The separation of aggregates in them happens too hard. The reasons are hardness, shape and better interlock of slags. Slags have proper resistance against wetting and drying, melting and freezing and abrupt changes of temperature and bearing chemical and corrosive materials and this is another reason to use them as ballast [10].

Figure 5: using slag in ballast

3.2 Application of blast-furnace slag at pavement layers stabilization

Advantages

1. Remarkably increases soil dry bulk weight.
2. Increases soil CBR more than cement and limestone.
3. The lowest settlement from vehicles loading happens on stabilized soil with slag.
4. Its resistance increase is not dependent on time and gives the best results in short term.
5. Due to its free initial materials is the first grade in terms of economic efficiency.
6. To stabilize with slag there is no need to long-term humidity in soil.
7. With regard to the change in soil gradation due to adding slag, it results in decreasing soil plasticity and efficiency increase.

Disadvantages

1. Increases fluidity level and paste mark and raises soil plasticity and reduces soil efficiency [12].

4 Conclusions

With regard to the high production rate of slags, these products create many problems in terms of pollution for environment which using it in road construction can help to reduce pollution.

Steel slag aggregate have base property (pH between 8 and 10). Steel slag in reaction with bitumen creates a resistance composition against humidity. So it shows appropriate strength against stripping phenomenon. Steel slag has sharp edges and rough surface. This issue helps the interlock among aggregates and increases the resistance against permanent deformation.

Asphalt admixtures including steel slags because of having sharp edge, pitted and high hardness surface have high friction strength. Steel slag has high polished stone value (PSV). High number of aggregate PSV raises friction resistance and increasing the safety of asphalt admixture level and surface stack. Using slag in pavement increases the resistance against rutting and reduces surface depression. Cubic shape property of slag material and its rough texture causes more resistance than smooth and round edge aggregates. Using slag in different pavement layers is possible.

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