

POTENTIAL USE OF PHOSPHATE WASTES AS AGGREGATES IN ROAD CONSTRUCTION

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Large quantities of solid wastes are generated in El-Nassar Mining Company at Sebaeya, Egypt as a result of mineral processing of phosphate ores. Over the years, the majority of these wastes have been stored in dumping areas which is aesthetically unattractive and degrading to the environment. However, these wastes, because of their similarity to conventional soils and aggregates, represent potentially useful sources of material for a variety of applications.

This paper is concerned with investigating the suitability of the coarse solid wastes generated from upgrading sebaeya phosphate ores as aggregates for road paving. The properties of these wastes are tested, according to the Egyptian Standard Test Methods for road constructions. The obtained results proved that this kind of wastes can be used in road construction. The positive uses of these wastes are considered beneficial from the economic and environmental point of view.

KEYWORDS: *Phosphate, waste utilization, road construction, aggregates, environmental cleaning*

INTRODUCTION

As high-grade Phosphate deposits are mostly depleted, the importance of low-grade deposits increases. Consequently, large quantities of solid wastes (about 1.5 million ton) are generated and accumulated as a result of processing these low-grade ores. Disposal of these wastes is becoming an acute environmental issue in addition to the added cost for their removal [1]. Waste utilization is an attractive alternative solution to the disposal of the solid wastes. This positive alternative saves disposal costs, reduces pollution problems, and conserves natural resources [2-3]. Most mineral wastes have limited potential for reuse because of their high impurity content or remote location. The mining industry has traditionally made use of its own waste materials, either by reprocessing to recover additional values, local construction purposes, or for land refill [3-4].

The basic mineral processing techniques involved in the milling and concentration of phosphate ores are crushing, screening, washing, classification, flotation and/or magnetic separation. As a result of preparation and beneficiation, two kinds of waste product are formed; coarse mill rejects from screening and fine mill tailings from washing and separation [4].

The quality of mineral processing of wastes varies widely and is highly dependent on the specific source. When the location and material property conditions are favorable, some sources of waste rock or coarse mill tailings may be suitable for use as granular base /sub-base, railroad ballast, aggregate in concrete and asphalt mixes [4-13]. Fine mill tailings, can be used as construction sand, an additive to concrete and asphalt mixes, in brick and block manufacture, in the manufacture of thermal insulation, for recovery of valuable minerals and in ceramic and pottery making [6-14].

Road construction today consists, generally, of four layers of aggregates as shown in Fig.1. These layers collectively are termed "the pavement". The type of aggregates and thickness of each layer depend on the type of the road and the use for which it is designed. The behavior of all layers is crucial to the stability and safety of the road [10- 11].

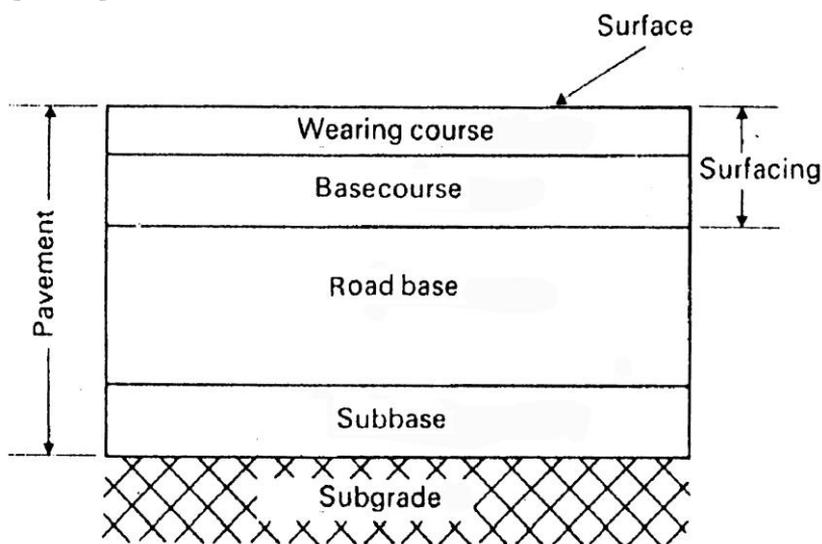


Figure 1: Structural layers in road construction [11].

Unbound granular materials of mill wastes are generally used in road construction applications as base / sub-base courses, which are important components of roads as surface composition and foundations [10-11]. As a base course, they play structurally important role, especially on medium and low volume roads. As a sub-base, they protect the soil, and act as working platform and an insulating layer against frost action. The favorite use of these solid wastes can be used locally in low-volume roads, where a lower quality aggregate is more appropriate [10]. The properties of road aggregates differ from road to another according to the road category. The main properties of aggregates are gradation, particle shape and texture, deleterious substances (clay and other contaminants), hardness (or resistance to wear), durability, crushing strength and compaction properties (maximum dry density and optimum water content) [6,10,11].

At Sebaeya, there are large accumulations of waste material produced from the phosphate milling plant [1]. As a result of beneficiation a coarse waste (over screen rejects) and fine tailings (e.g., clays, silica sand, dolomite, etc.) were

generated from the washing plant. The accumulation of solid wastes constitutes environmental problems and must be removed. The main objective of this investigation is to evaluate the possibility of using solid wastes generated from the beneficiation of Sebaeya phosphate in road construction as base or sub-base aggregates. The substantial benefits of using these waste materials for road building purposes can be summarized in the reduction of costs, and solution of the environmental problems.

EXPERIMENTAL WORK

Material

Head sample of 200 kg solid wastes (over screen reject) was obtained from Sebaeya phosphate dump. The sample is thoroughly mixed and divided by coning & quartering into two portions, one for road paving tests and the other was kept to be used for the other purposes. The portion of the sample used in this investigation was crushed to pass 40 mm (the maximum size for road base/sub-base construction). The head sample assay was 21.65% SiO₂, 42.95% CaO, 0.40% Na₂O, 0.03% K₂O and 8.74% L.O.I.

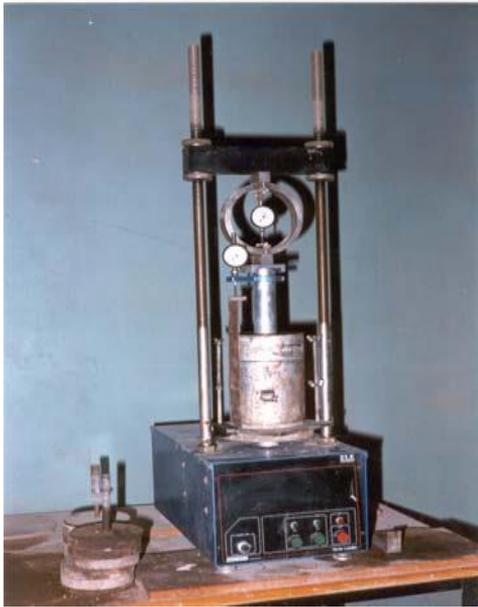
Procedures

The most important aggregate quality tests are:

- 1- Physical properties: such as particle shape, texture, true density, bulk density, water adsorption and deleterious substances. Details of the test procedure are given in reference [11, 15].
- 2- Gradation (Grain size analysis): The purpose of this test is to obtain a specific grain size distribution of the aggregates. The standard set of screen used in aggregate gradation are: 2.0 inch, 1.5 inch, 1.0 inch, $\frac{3}{4}$ inch, $\frac{3}{8}$ inch, 4 mesh (4.75 mm), 10 mesh (2.0 mm), 40 mesh (0.425 mm), and 200 mesh (0.075 mm). The test procedure is given elsewhere [11, 15, 16].
- 3- The standard compaction test: (compacted density and moisture adsorption): This test also known as the moisture-density test. It measures the maximum dry density that aggregates can reach under a specified compaction stress, and amount of water adsorbed at maximum dry compacted density. The apparatus used consists of standard compaction mold, standard compaction hammer, balance, and dry oven as shown in Fig. 2. The procedure is given in details elsewhere [11].
- 4- California Bearing Ratio (C B R): The California Bearing Ratio test is one of the common methods to evaluate the strength of sub-grade quality aggregates for pavement design [11].

The procedure of the test is given in details in references [16-17], and the apparatus is shown in Fig. 2.

- 5- Los Angeles Abrasion test: This test is an accepted measure of the hardness of coarse aggregates (-38+2.0mm size). Figure 3 shows the Los Angeles apparatus and the procedure of the test is given in detail in references [11, 16].



(2 a)



(2 b)

Figure 2: (a) California Bearing Ratio (CBR), (b) Standard compaction test (proctor's test).



Figure 3: Los Angeles abrasion apparatus

- 6- Slake Durability test: It measures the aggregates durability (resistance to weathering) expressed in Id₂ values. When these values approach zero for a sample, this means that the sample is highly susceptible to slaking, and when they approach 100%, this means that this material is a rocklike material that is slightly slaking. The apparatus used is shown in Fig. 4, and the procedure of the test is given in details in references [17].
- 7- Crushing strength test: The aggregates used in the base and sub-base for road construction should be hard to resist grinding action, and strong to withstand heavy loads. The crushing strength of coarse aggregates is

expressed as the "Aggregate crushing value" which is the percentage of minus 2.5 mm material in the crushed load. Fig. 5 shows the apparatus used for this purpose and its schematic drawing in action. The procedure of the test is given in details in references [11, 16].

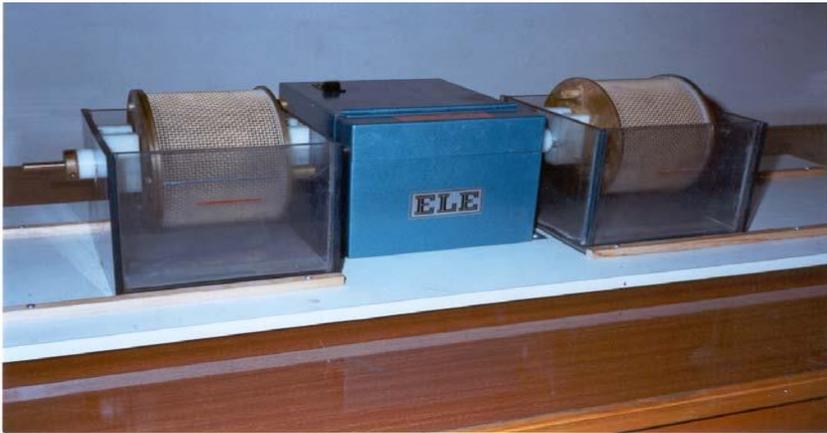
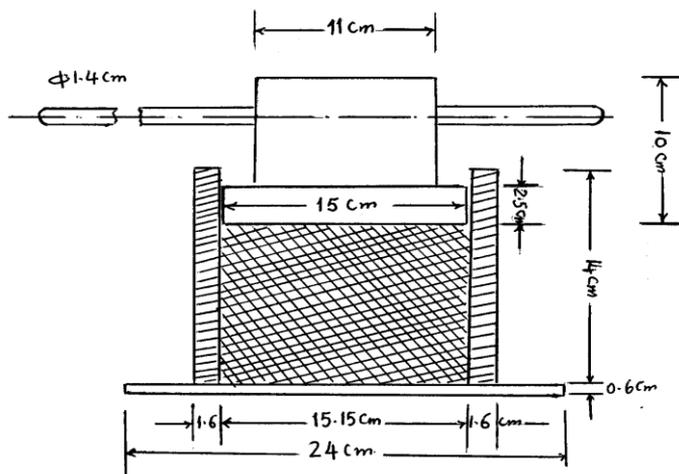


Figure 4 : Slake durability test apparatus



(5a)



(5b)

Figure 5 (a & b) :The Two Parts of crushing strength apparatus

RESULTS AND DISCUSSION

The required specifications of aggregates depend on the purpose in which they will be used. There are no standard specifications for mill waste materials as aggregates in granular base or sub-base of road construction. The aggregates must meet size requirements; satisfy standard Proctor moisture-density criteria and a minimum durability value, in addition to restricted physical and chemical properties. Tables 1 through 4 states the various test values as measured for the Sebaeya phosphate coarse aggregates. These values are compared with the corresponding standard values in the same tables.

1- Physical and chemical properties: The measured as well as the standard values of each property, whenever there is a corresponding standard value, are shown in Table 1.

Table 1: Physical and chemical properties of Sebaeya phosphate aggregates.

The standard values are taken from references 4, 9, 11, and 15.

Property	Measured values	Standard values
Particle shape	Irregular	-
Surface texture	Rough	-
True density , g/cm ³	2.655	2.0-2.3
Bulk density , g/cm ³	1.4	-
Water adsorption, wt. %	6.0	<10
Deleterious substances, wt. %	1.51	< 3
Chlorine ion , wt %	0.0238	<0.04
Sulfate ion, wt. %	0.0709	<0.4
pH	7.60	Alkaline

Table 2-a: Gradation of aggregates used in road construction, measured and standard values [15].

Size range	Measured distribution		Standard distribution	
	Frequency , wt %	Cum. Pass, wt %	Frequency , wt %	Cum. Pass, wt %
1.5 in+1.0 in	6	100	15	100
1.0 in+ 3/4 in	11	94	10	70-100(85)*
3/4 in +3/8 in	33	83	15	60-90 (75)
3/8 in + 4 mesh	34	50	15	45-75 (60)
4 mesh + 10 mesh	7	16	10	30-60 (45)
10 mesh + 40 mesh	2	9	15	20-50 (35)
40 mesh + 200 mesh	2	7	12.5	10-30 (25)
200 mesh	5	5	7.5	5-15 (7.5)

* Average values for the size fractions in the standard values.

All the measured values for the phosphate waste aggregates are within the standard values as stated in the literature [15].

2- Gradation: One of the important specifications of the road construction materials is the size distribution of the aggregates. Table 2-a presents the gradation of Sebaeya phosphate aggregates and the corresponding standard distribution of the road construction materials.

From Table 2-a, there is disagreement between some of the measured values and the standard ones. The size fractions can be grouped into 3 groups as shown in Table 2-b.

Table 2-b: Size fractions combined into three groups (measured & standard).

Size fractions	Measured frequency, wt. %	Standard frequency, wt. %
1.5 in + 3/4 in	17	25
3/4in + 4 mesh	67	30
4 mesh	16	45

In this case, the mismatch can be corrected simply by crushing 50% of the fraction -3/4 inch + 4mesh to pass 4 mesh screen. This will reduce the -3/4in + 4 mesh to about 33% (the standard value is on the average 30 %), and increase the minus 4 mesh to about 50% of the total sample weight (the standard minus 4 mesh is on the average 45 %). This operation makes the measured values match the standard values.

3- Relative dry density, water adsorption and California Bearing Ratio (CBR) are tested by carrying out the standard compaction test on the solid aggregates. The obtained results as well as the Egyptian standard values are given in Table 3.

Table 3: Relative density, CBR, Los Angeles, and Slake Durability results of solid wastes for road construction.

Test	Measured Values	Standard Values*
Dry density, g/cm ³	1.95	1.6-2.025
Water adsorption, %	13	10-18
CBR, %	69.7	< 25
Los Angeles Values, %	45.2	< 50
Slake Durability, id ₂ %	93.98	Approach 100

* References [9,10,15,17]

4- Crushing strength: The crushing strength test results for three replicates carried out for evaluating the crushing strength of Sebaeya phosphate waste aggregates are given in Table 4.

Table 4 : crushing strength test results for Sebaeya phosphate aggregates.

Item	Test 1	Test 2	Test 3
Weight of empty mortar, g	6225	6225	6225
Weight of compacted mortar, g	9480	9420	9370
Net Weight of aggregate, g	3255	3195	3145
Weight of crushed ore (- 2.5 mm) ,g	950	965	900
Crushing strength , %	29.18	30.2	28.62
Average measured crushing strength, %	29.33		
Standard crushing strength, %	Not more than 30		

The average crushing strength percent for the three replicates is reproducible. The average measured value of the crushing strength percent is 29.3 %, which is within the limits of the standard value.

From tables 1 through 4, it is clear that, the quality of phosphate wastes aggregates, as over screen reject from Sebaeya beneficiation plant, matches the Egyptian standard specification of natural materials used in road construction.

SUMMARY AND CONCLUSIONS

The obtained results in this research work, as correlated with the standard values, can be summarized as follows:

- 1- The properties (physical, chemical and mechanical) of coarse phosphate waste aggregates from Sebaeya phosphate beneficiation plant are similar to those of conventional mineral aggregates used in road construction and water-bound macadam roads (WBM).

- 2- The deviation of the size grading of the used sample from the standard specifications can be corrected by crushing part of the -3/4 inch + 4 mesh size fraction.
- 3- The produced aggregates can be safely used in the construction of local low – volume roads.
- 4- The use of solid wastes as aggregates in road construction can be a positive solution to remedy the environmental problems created by dumping these wastes in the open area surrounding the plant. This is an urgent demand for the surrounding society. In addition, the cost per ton of phosphate product will be reduced by omitting the transportation cost of the waste material.
- 5- Saving in cost of material used for road construction (i.e. no mining, crushing and transportation costs) are required. In addition, it conserves the natural resources that could have ,otherwise, been use for road construction.

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الاستخدام الإيجابي لنفايات الفوسفات كركام في تأسيس الطرق

تتراكم كميات كبيرة من النفايات الصلبة ناتج مرحلة الغريلة لعملية تركيز خام الفوسفات بمنطقة السباعية شرق . وتشون هذه النفايات في أكوام في مناطق قريبة من مصنع تركيز الفوسفات والتي بدورها تؤدي إلى تلوث البيئية المحيطة . ونظرا لتشابه خواص هذه النفايات مع التربة والركام الطبيعي فإنها أصبحت مصدرا للاستخدام في كثير من التطبيقات .

وفي هذا البحث تم التركيز على دراسة ملائمة النفايات الصلبة الناجمة من عملية الغريلة كركام يصلح في تأسيس الطرق البرية المحيطة بمنطقة العمل.وقد تم دراسة واختبار خواص هذه النفايات طبقا للمواصفات المصرية القياسية في تنفيذ الطرق البرية والخلوية. ومن النتائج العملية تؤكد مدى ملائمة هذه النفايات للاستخدام كركام في تأسيس الطرق البرية والخلوية وخاصة بمناطق التعدين . والاستخدام الإيجابي لهذه النفايات يعتبر مفيد من حيث كونها تقلل من الاعتماد على المصادر الطبيعية للركام وتحد من المخاطر البيئية الناجمة عن تراكمها .