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Black sands applications in Construction and Building

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ABSTRACT

Black sand is sand that is black in color, there are a number of different dark sand grains that can form black sand, it concentrates often contain additional valuables, other than precious metals: rare earth elements, thorium, titanium, tungsten, zirconium and others are often fractionated during igneous processes into a common mineral-suite that becomes black sands after weathering and erosion, several gemstones such as garnet, topaz, ruby, sapphire, and diamond are found in placers and in the course of placer mining, and sands of these gems are found in black sands and concentrates. black sand is found in Egypt with economical quantities, it is located in the Mediterranean sea coast from Al Arish in north Sinai to Rashid in Al Buhayrah, the main concentration of black sand is in Kafrelshiekh. Black sand is considered as source of many ores used in building and construction such as Iron and steel industry, that is beside wide application in concrete and painting industries. In this work, Chemical, physical and mechanical characteristics of black sands compounds in Egypt are mentioned,

the composition and locations of black sand will be discussed, the main common applications of black sands in building and construction industries will be mentioned, the application of black sands in insulation materials industries will be discussed the disadvantages and precautions of using black sands in some applications in buildings will be evaluated. The work end with group of results and recommendations to improve the economic of black sand applications in new fields related to construction and building material industries such as Titanium industries and composite materials.

Keywords: black sands, minerals, construction, buildings

INTRODUCTION

Black sand is sand that is black in color [1]. One type of black sand is a heavy, glossy, partly magnetic mixture of usually fine sands, it found as part of a placer deposit. Another type of black sand, found on beaches near a volcano, it consists of tiny fragments of basalt. Dark color and heavy metal content are both caused by high iron content[2-7]. Iron gives black color to most minerals because it absorbs light very well and it is also heavy in density. Such sands are heavier than 'normal' light-colored sands and become very hot on a sunny day [8]. **black sands are distributed in many places all over the world table (1) shows locations of them[9]**

While some beaches are predominantly made of black sand, When lava contacts water, it cools rapidly and shatters into sand and fragmented debris of various size[10-12]. Much of the debris is small enough to be considered sand [13]. A large lava flow entering an ocean or sea may produce enough basalt fragments to build a new black sand beach almost overnight such as black sands in Egypt. Figure (1) and figure (2) show the black sands area in Egypt[14-17]. Black sands occur along the Mediterranean coastal plain North of the Nile Delta [18], especially at the Nile outpourings near Rosetta and Damietta [19-20. These are beach placers deposited from the Nile stream during flood seasons reaching the Mediterranean Sea at river mouth [21].

Table1: Black sand locations and beaches in various places [22-25]

Continent\ location	country	Location
Europe	Greece	Santorini-Mykonos
	Iceland	Vík í Mýrdal-Reykjanes
	Portugal	Azores
	Spain	Tenerife
Asia	Taiwan	Kaohsiung
North Atlantic	Iceland	Vík í Mýrdal,
South Pacific	New Zealand	Kariotahi Beach, (ironsand) Muriwai Black Sand Beach, Piha, (ironsand) Raglan,
	Tahiti	Tautira Point Venus
Indian Ocean	Indonesia	South coast of Java, (ironsand)
America	United states	Prince William Sound, Alaska, Lost Coast, California
	Hawaii	Big Island Punalu'u Beach Kehena Beach Kaimū, Hawaii (destroyed by lava flow in 1990)
	Maui	Honokalani, Waiʻanapanapa, Waiʻanapanapa, State Park Oneʻuli Beach[7](Naupaka Beach)[8]
	Mexico	Playa Patzcuarito (Nayarit) Playa La Ventanilla (Oaxaca)
	Costa Rica	Playa Negra
	Panama	Las Lajas, Chiriquí Province[9]
Caribbean		Saint Vincent and the Grenadines Montserrat (most beaches except Rendezvous Beach) St. Eustatius St. Kitts Nevis Jamaica Dominica (most beaches) St. Lucia Anse Chastanet Grenada Venezuela Puerto Rico (Barceloneta, Machuca's Garden) Puerto Rico, Vieques Playa Prieta

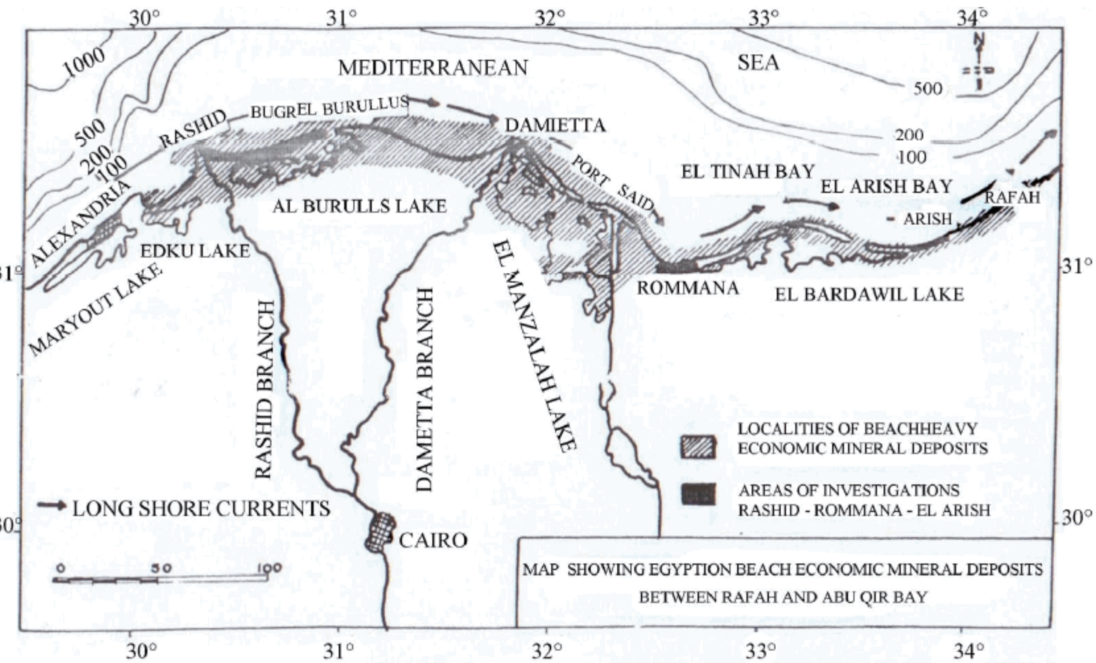

Figure 1: black sands occurrence in Egypt [7]

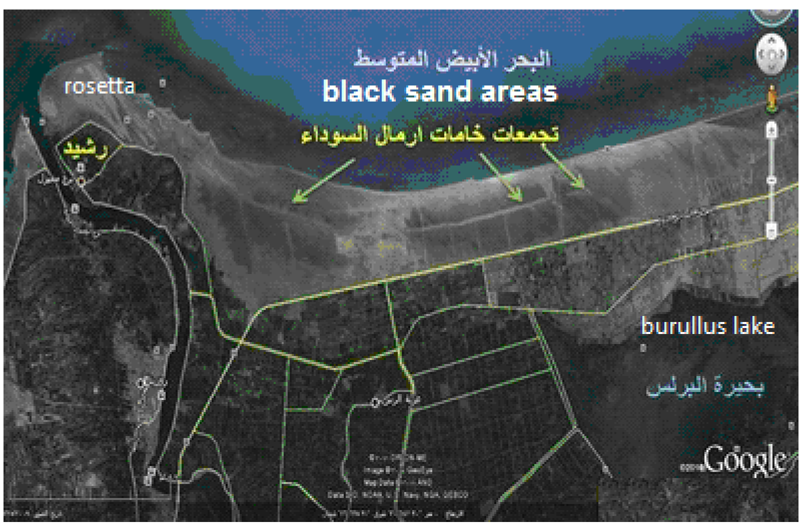

Figure 2: Google earth photo for black sands [8]

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The main components in black sands

Basalt and heavy minerals are the most common constituent rocks of black sand [11].

Basalt

Basalt is dark igneous rock that is low in silica content and comparatively rich in iron and magnesium. Some basalts are glassy (have no visible crystals), and many are very fine-grained and compact, table (2) and figure (3) show the main composition of basalts. Basalt is a hard, black volcanic rock with less than about 52 weight percent silica (SiO2). Common minerals in basalt include olivine, augite, pyroxene, and plagioclase. Basalt is erupted at temperatures between 1100 to 1250° C. When basalt is beneath the surface it is called lava, when it is outside the earth's crust, it is basalt[15].

Table2: The main composition of basalt [12]

Composition	**SiO_2**	**TiO_2,**	**FeO**	**Al_2O_3**	**CaO**	**MgO**	**Total alkalis**
Wt %	**45–55**	**0.5–2.0**	**5–14**	**14**	**10**	**5 - 12**	**2–6**

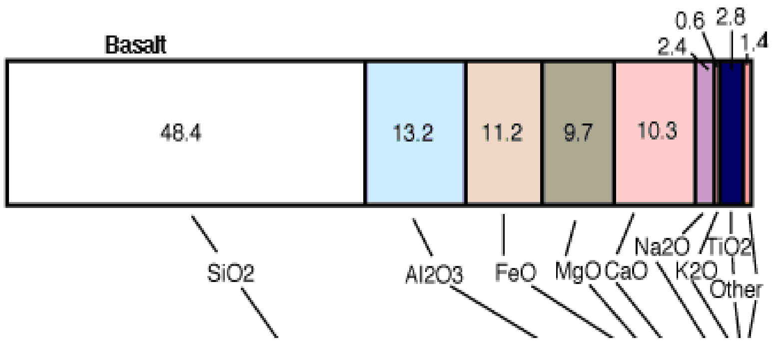

Figure3: Main compounds of basalt [25]

SiO2 = silica, **Al2O3** = Aluminum oxide, **FeO** = total iron oxide, **MgO** = magnesium oxide, **CaO** = calcium oxide, **Na2O** = sodium oxide, **K2O** = potassium oxide, **TiO2** = titanium oxide, **Other** = other elements.

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Values are weight percent oxide

High alumina basalts have aluminium contents of 17–19 wt% Al_2O_3; boninites have magnesium contents of up to 15% MgO. Rare feldspathoid-rich mafic rocks, akin to alkali basalts, may have Na_2O plus K_2O contents of 12% or more [15-18].

Heavy mineral sand.

Heavy minerals are minerals which have a specific gravity above 2.9. There are almost all colors present among the heavy minerals but they seem to be dark compared to usually light-colored quartz sand. Heavy mineral sands are usually composed of minerals that are relatively resistant to weathering. Such minerals are tourmaline, magnetite, garnet, rutile, ilmenite, zircon, Monazite [11-13].

Heavy minerals are in most cases disseminated among the light-colored (and usually much larger) quartz grains but in certain conditions they tend to accumulate[16].

There are two types of black sands: the concentrated ore, which is very dark in color and contains 70- 90% of heavy minerals, and the diluted ore, which is lighter in color and contains up to 40%. The black sands contain some economic minerals such as ilmenite, hematite, rutile, magnetite, zircon, garnet, and monazite [16]. Some areas were studied in details. Just an example: the reserves of economic minerals at Rashid area are as shown in figure (4) (in 1000 tons) [20-22].

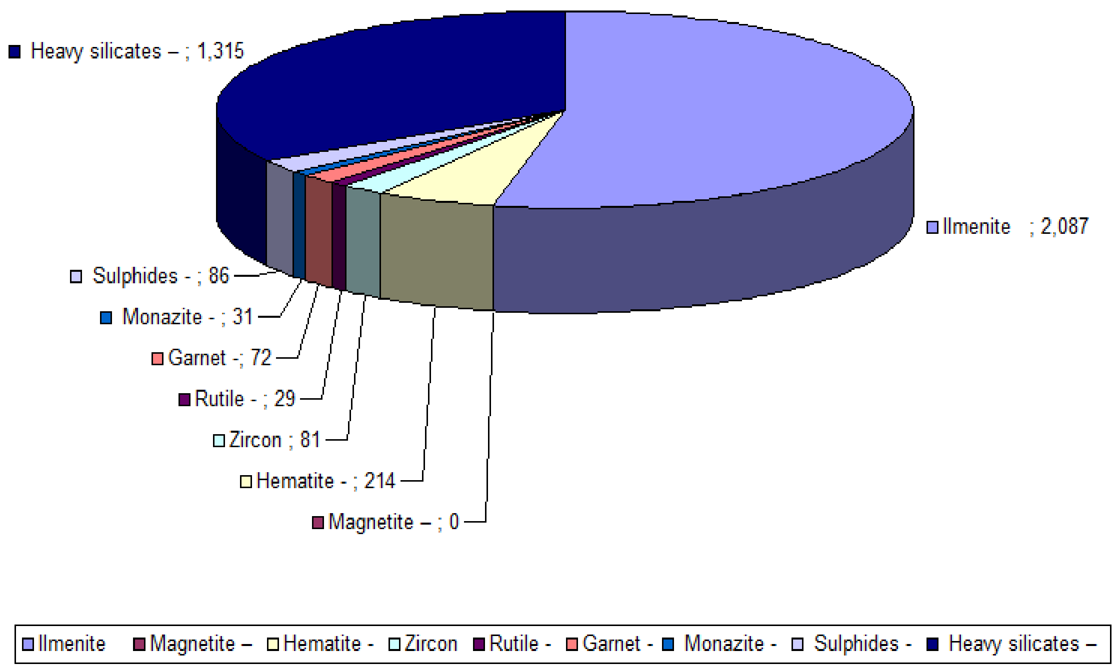

Figure4: The composition of black sands in Egypt [17]

The black sands compounds and their composition and descriptions are found in the table (3), while the physical properties of each compound were explained in table(4), the compounds have relatively higher hardness more than 5 to 7 and specific gravity in the range from 3 to 5 with different color, streak and cleavages [11-13].

Table3: Main compounds in black sands

Compound		Composition	Description
Olivine		(Mg,Fe,Mn,Ca)2SiO4	An abundant mineral in mafic and ultra-mafic igenious rocks,
Olivine	**Forsterite**	Mg_2SiO_4	
	Fayalite	Fe_2SiO_4	
	Tephroite	Mn_2SiO_4	
	Monticellite	$CaMgSiO_4$	

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<table>
<tr><td colspan="2">tourmaline</td><td>(Na,Ca)(Fe,Mg,Al,Li)3Al6(BO3)3Si6O18(OH)4</td><td>Means brown (the color of some tourmaline gemstones) ,ring silicates have structures consisting of planar rings of silica tetrahedral</td></tr>
<tr><td colspan="2">Magnetite,</td><td>Fe3O4</td><td>Various igneous and metamorphic rocks banded iron formation beach black sand</td></tr>
<tr><td colspan="2">Garnet,</td><td>($X_3Y_2Si_3O_{12}$ where X-Mg, Fe, Ca and Y-Al, Fe, Cr)</td><td rowspan="4">The garnets all have chemistries $A_3B_3Si_3O_{12}$,
Their structure consists of isolated silicate $(SiO_4)^{-4}$ it containing ions such as (Al^{3+}, Fe^{3+}) and ions such as $(Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+})$</td></tr>
<tr><td rowspan="3">Garnet</td><td>Pyrope</td><td>$Mg_3Al_2Si_3O_{12}$</td></tr>
<tr><td>Almandine</td><td>$Fe_3Al_2Si_3O_{12}$</td></tr>
<tr><td>Spessartine</td><td>$Mn_3Al_2Si_3O_{12}$</td></tr>
<tr><td colspan="2">Rutile</td><td>TiO2</td><td>Microscopic crystal in granites, granitic pegmatites, gneisses, schists, marbles and quartz grains</td></tr>
<tr><td colspan="2">Ilmenite</td><td>FeTiO3</td><td>Hexagonal Gabbros diorities anorthosites, pegmatites, some manetite -rich (black) beach sands</td></tr>
<tr><td colspan="2">Zircon</td><td>ZrSiO4</td><td>Colorless or pale yellow or brown and faintly pleochroic. Grains are typically small due to decay of radioactive elements.</td></tr>
<tr><td colspan="2">Monazite</td><td>(Ce, La, Nd, Th) PO_4</td><td>Radioactivity, color rare occurrences, crystal, high density and not hard</td></tr>
</table>

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Table4: The physical properties of black sand compounds [17-19]

Compound \ Property		Hardness	Specific gravity	Cleavage	Fracture	Luster	transparency	color	streak
Olivine	Forsterite	6.5	3.2	Poor(010)&(100)	Conchoidal	vitreous	Transparent to translucent	Colorless Or green	white
	Fayalite	6.5	4.4	Poor(010), (100)	Conchoidal	vitreous	Transparent to translucent	Green to yellow	White yellow
	Tephroite								
	Monticellite	5.5	3.15	Poor(010), (100)	Conchoidal	vitreous	Transparent to translucent	Colorless ,gray, or green	white
Tourmaline		7-7.5	2.9	Poor{101}, Poor{110}	Sub-conchoidal	resinous	Transparent	Variable black, blue, Green, Red, Colorless, often zoned	white
Magnetite,		6	5.20	none	Sub-conchoidal	metallic	opaque	black	black
Garnet,	Pyrope	7	3.54	none	Sub-conchoidal	resinous	Transparent to translucent	Red, Occasionally black	white
	Almandine	7	4.33	none	Sub-conchoidal	resinous	Transparent to translucent	Deep red	white

Spessartine	**7**	**4.19**	**none**	**Sub-conchoidal**	**resinous**	**Transparent to translucent**	**Pink to violet**	**white**
Rutile	**5-6**	**4.24**	**Good prismatic {100},{110}**	**Sub-conchoidal**	**Adamantine, submetallic**	**Transparent to translucent**	**Red, red brown to black**	**Pale or Light brown**
Ilmenite	**5.5-6**	**4.5 -5**	**none**	**Sub-conchoidal**	**metallic**	**opaque**	**Iron-black**	**Brownish red to black**
Zircon	**7.5**	**4.68**	**Poor (100), {101}**	**Conchoidal**	**Adamantine,**	**Transparent to translucent**	**Brown to green, Gray red, colorless**	**Colorless To white**
Monazite	**5-5.5**	**4.9-5.2**	**Perfect (001), good(100)**	**Sub-conchoidal**	**Variable, subresinous**	**translucent**	**Red, brown, yellowish**	**white**

The main applications of black sands

Iron and steel industry

Ores containing very high quantities of hematite or magnetite (greater than ~60% iron) are known as "natural ore" or "direct shipping ore", meaning they can be fed directly into iron-making blast furnaces. Iron ore is the raw material used to make pig iron, which is one of the main raw materials to make steel. 98% of the mined iron ore is used to make steel.[2] Indeed, it has been argued that iron ore is "more integral to the global economy than any other commodity[12].

Magnetite

Magnetite is magnetic, and hence easily separated from the gangue minerals and capable of producing a high-grade concentrate with very low levels of impurities[22].
The grain size of the magnetite and its degree of commingling with the silica groundmass determine the grind size to which the rock must be comminuted to enable efficient magnetic separation to provide a high purity magnetite concentrate. This determines the energy inputs required to run a milling operation.
Mining of banded iron formations involves coarse crushing and screening, followed by rough crushing and fine grinding to comminute the ore to the point where the crystallized magnetite and quartz are fine enough that the quartz is left behind when the resultant powder is passed under a magnetic separator[6].
Generally most magnetite banded iron formation deposits must be ground to between 32 and 45 micrometers in order to produce a low-silica magnetite concentrate. Magnetite concentrate grades are generally in excess of 70% iron by weight and usually are low phosphorus, low aluminium, low titanium and low silica and demand a premium price[8-12].

Hematite

Due to the high density of hematite relative to associated silicate gangue, hematite beneficiation usually involves a combination of beneficiation techniques[24].
One method relies on passing the finely crushed ore over a slurry containing magnetite or other agent such as ferrosilicon which increases its density. When the density of the slurry is properly calibrated, the hematite will sink and the silicate mineral fragments will float and can be removed.[5]

Painting industries

Decorative colors of black sand compound is very important source of natural colors in painting industries, the fine powders resulting from mining of black sand compound and ore dressing can be used as pigments in painting industries specially oxides with decorative tiles[3].

Titanium industries

Rutile and ilmenite are the main sources of titanium in black sands, Titanium is the ninth most abundant element and the fourth most abundant structural metal in the earth's crust. Approximately 95% of titanium mined is consumed in the form of titanium dioxide, $TiO2$, for pigments, papers, plastics, and other materials. Pigment is the largest consumer of all the titanium mined [8-12]. Paints, varnishes, and lacquers comprise about 50% of the market while paper consumes about 23% and plastics account for 18%. Ceramics, fabrics, textiles, floor coverings, printing, ink, and rubber consume the balance of 9%. In paint, $TiO2$ provides durability, gloss, and brightness as well as providing resistance to abrasion, chemical attack, and heat. For plastics, $TiO2$ provides opacity and protection from UV degradation. Rutile-based pigments are the preferred choice for most plastics. In contrast, paper applications employ the pigments, as they are less abrasive to papermaking machinery [1]. In modern metallurgy the titanium alloys are considered as the black horse alloys in different construction and industrial applications[14].

Innovation of using Titanium as building material :

a) Basic characteristics of Titanium as building material can be applicable under highly corrosive environment .
b) Titanium material with a wide variety of surface is suitable for temples and shrines to modern architecture .
c) Anti-discoloration : as it doesn't easily become discolored with passage time.
d) A wealth of application technology : as it has a little distortion during formation and also a suitable cleaning agent.
e) Titanium dioxide (TiO_2) particularly nano-particles can be used to realize transparent self-cleaning coatings on several kind of surfaces , even on stone , limiting cleaning and maintenance actions , this reducing their costs and improving the quality of treated surfaces . The self-cleaning ability of titanium dioxide is due to the synergy of its own photo-induced properties activated by solar light : superhydrophilicity and photocatalysis.
f) Minimize the thermal expansion and thermal conductivity.
g) Environmental sound : as titanium is friendly metal to humans and environment.
h) Applications in self-cleaning and antibacterial coatings for industrial products.
i) Application of the spray-coating technology the aqueous or methanolic TiO_2 suspension is sprayed on the surface of the considered building material. This method has the advantage that the amount of TiO_2 which shall cover a specific area of the sample can be regulated in a simple way. After spraying , the solvent can be removed by heating the sample to approx. 100°C.
j) Application of the sedimentation technology the sample is kept for a defined time in a TiO_2 suspension . Then the suspension slowly is drained from the breaker . Again , the solvent can be removed by heating the sample to approx. 100(C.

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k) The photocatalytic of the TiO2 as building material , particularly when applied to infrastructural works , can contribute to clean the air and improve sustainability levels [20-25].

Aluminum industries

The aluminum foundry industry uses olivine sand to cast objects in aluminium. Olivine sand requires less water than silica sands while still holding the mold together during handling and pouring of the metal. Less water means less gas (steam) to vent from the mold as metal is poured into the mold[18].

Composite material

The hardness and optical characteristics of some compounds in the black sands make it as natural reinforcement in composite material industry, in some compounds the hardness ranges from 5 to 6[18].

Nanotechnology

The trend in nanotechnology to find nano-materials from natural resources to reduce the cost of preparation of nano-materials and find nano material with huge amounts suitable for economical applications. Black sand mining and extraction introduce wide range of very fine powder suitable for different applications in nano-technology with economical amounts[6-8].

Concrete industries

Basalt is the best reinforcement for concrete due to its Tensile Strength and natural resistance to deterioration from alkali. Basalt based composites can replace steel and all known reinforced plastics (1 kg of basalt reinforcement equals 9.6 kg of steel) [14].

Insulation materials industries

The main use of basalt which is the main compound in black sands is as a crushed rock used in construction, industrial and highway engineering. However it is not commonly known that basalt can be used in manufacturing and made into fine ,superfine and ultra fine fibers. Comprised of single-ingredient raw material melt, basalt fibers are considered superior to other fibers in terms of thermal stability, heat and sound insulation properties, vibration resistance and durability [11-19].

Basalt products have no toxic re-action with air or water, are non-combustible and explosion proof. When in contact with other chemicals they produce no chemical reactions that may damage health or the environment. Basalt replaces almost all applications of asbestos and has three times its heat insulation properties [14]. The life of basalt fiber pipes, designed for a variety of applications, could be at least 50 years without maintenance or electrical or technical protection. Basalt fibers together with carbon or ceramic fibers as well as various metals is one of the most advanced and exciting area of application, as they can develop new hybrid composite materials and technologies basalt is the main raw material in Rockwool industries [15-19]. it used as filler for gypsum and sheetrock board requiring increased 'burn-thru' capability, to meet building regulations

Disadvantages and precautions of using black sands

Some compounds of black sands have radioactive characteristics, it is about 4% from total content of black sands. Table (5) shows the radioactive elements in the black sands, the energy resulting from dissociation, decay type and half life time. the radioactive materials with short life time must be separated from black sands before using it as building materials [22].

Table (5) Radioactive materials in black sands[25,11]

Decay	Energy MeV	Main decay type	Radioactive half life, sec
Strontium-90	0.54 + 2.28	beta	8.8×10^{8} or 28 yrs
Thorium-232	4.0	alpha	4.5×10^{17} or 1.4×10^{10}yrs
Uranium-238	4.27	alpha	1.4×10^{17} or 4.5×10^{9}yrs

CONCLUSIONS

1.The Egyptian black sands are the end products of the disintegrated materials from the igneous and metamorphic rocks.

2.The Egyptian black sand deposits comprise huge reserves of the six common economic minerals [4-6] that include ilmenite ($Fe^{2+}TiO_3$), magnetite ($Fe_2^{3+}Fe^{2+}O_4$), garnet ($X_3Y_2Si_3O_{12}$ where X-Mg, Fe, Ca and Y-Al, Fe, Cr), zircon ($ZrSiO_4$), rutile (TiO_2) and monazite (Ce, La, Nd, Th) PO_4

3.Black sands have reasonable concentration of the following elements concentrations of titanium (Ti), vanadium (V), Chromium (Cr), Manganese (Mn), iron (Fe), zinc (Zn), arsenic (As), zirconium (Zr), cadmium (Cd) and hafnium (Hf).

4.the mineralogy of these black sands give indication about their economics

5.Black sand is sand that is black in color. It seems to be very simple. there are a number of different dark sand grains that can form black sand and hence there are several different ways how black sand can form

6.The realm of black sands can be broadly divided into two parts, both of them having subdivisions. The most widespread type of black sand is composed of volcanic minerals and lava fragments.

7.Dark color and heavyness are both caused by high iron content. Iron gives black color to most minerals because it absorbs light very well and it is also heavy.

*8.*Basalt is the most common source rock of black sand

*9.*Black volcanic sands may contain many non-black grains like green olivine crystals

10. Heavy mineral sands are usually composed of minerals that are relatively resistant to weathering. Such minerals are tourmaline, magnetite, garnet, rutile, ilmenite, and zircon.

RECOMMENDATIONS

1.Black sands are considered as valuable wealth in Egypt, and so many industries can be developed in Egypt based up on this wealth

2.Research institute related to mining wealth in Egypt must be established to enhance new industries based up on black sands

3.New group of factories must be established to deal with different applications of black sands

4.Training center must be established to introduce human resource to all industries based on black sand applications

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