International Journal of Chemistry and Material Science Vol. 3(1), pp. 012-024, February 2015
Available online at http://academeresearchjournals.org/journal/ijcms
ISSN 2327-5553 ©2015 Academe Research Journals

Full Length Research Paper

Geochemical and mechanical studies of nonmetallic ores utilized as blasting abrasive media for surface preparation of metallic surfaces

Mohamed A. Wahab A. Halim* and Ibrahim H. Ibrahim

Egyptian Petroleum Research Institute (EPRI), Exploration Department, Nasr City, Cairo, Egypt.

Accepted 30 November, 2014

The metal surface effects produced with various blasting abrasives can range from deep cutting to gentle scouring of the surface. Important factors to consider in selecting an abrasive include: type of surface to be cleaned, shape of the structure, type of material to be removed, surface finish desired, profile, breakdown rate of the abrasive, reclamation of the abrasive, and hazards associated with the use of the abrasive. The types of available abrasives vary from one part of the country or the world to another. The general categories are: steel shot, metal grit, and mineral abrasives. Naturally occurring ores includes, sand, garnet, ilmenite, and white sand are probably the most commonly used for blast cleaning of metallic surfaces before applying protective painting. This study covers the specification and the quality of some nonmetallic ores (sand, garnet, ilmenite, white sand), utilized as abrasive materials used in the blast cleaning of metal surface such as petroleum construction projects, ships, hulls and tanks to remove rust, scale, old paint and marine growth, and also to provide the required anchor "profile" necessary for bonding of paint layers with metal substrate. The study program shall compare between the physical, chemical and mechanical properties of Egyptian, Indian, Chinese and Austrian ores to demonstrate the complete figure for the proper abrasive media that can achieve the standard metal surface preparation before applying protective coatings in the oil, gas, petrochemical construction projects. The evaluation techniques used to evaluate the quality of the various nonmetallic abrasive ores incorporated laboratory and field testing including physical properties (specific gravity, moisture content, pH value, particle size distribution, free flow, conductivity, oil content, hardness), chemical analysis and field particle testing. The study indicates that the GMA Australia garnet, Egyptian garnet, China and Indian garnet gives a very good result for steel surfaces cleaning, profile, no dust contamination and very low level of salt contamination in comparison with other nonmetallic ores.

Key words: Nonmetallic ores, surface preparation, blasting, abrasive media, surface cleaning.

INTRODUCTION

Surface preparation is the key factor in determining the success of a protective coating system. The equipment and techniques that can be used to achieve the desired surface cleanliness and roughness (profile) vary considerably as shown in Table 1.

The ultimate objective of surface preparation is to create proper adhesion of a coating over an underlying substrate. Adhesion is the key to coating effectiveness. It determines whether the coating is merely a thin film lying on the surface or if it becomes an actual part of the substrate. Adhesion is even more critical for coatings subjected to corrosive or immersion environments. Proper surface preparation is vital to the service life and overall effectiveness of a coating for protection of the substrate. The purpose of surface preparation is twofold.

*Corresponding author. E-mail: mgaber01@hotmail.com. Tel: +2 01001934013.

Table 1. Metallic surface preparation "cleanliness" standards.

Variable	USA specifications		Canadian Government	British standard	Swedish Standard	Japanese standard
	SSPC	NACE	CGSB	4332	SIS 05 5900	SPSS
White metal	SSPC-SP 5	Grade 1	Type 1	First quality	Sa 3	JASh3 or JASd 3
Near white metal	SSPC-SP 10	Grade 2	N/A	Second quality	Sa 2½	JASh2 or JASd 2
Commercial blast	SSPC- SP 6	Grade 3	Type 2	Third quality	Sa 2½	JASh1 or JASd 1
Brush off blast	SSPC- SP 7	None	Type 3	None	Sa 1	None

Figure 1. Samples from naturally occurring ores showing: (a) garnet abrasive; (b) sand; (c) white sand; and (d) ilmenite.

The surface must be roughened, providing an increased surface area for a mechanical bonding of the coating to the substrate. This roughening is commonly referred to as anchor pattern or profile, and it is essentially a pattern of peaks and valleys etched into the surface. This pattern is most commonly obtained by abrasive blast cleaning, although it can be obtained by the use of certain power tools which simultaneously clean and roughen the surface. Metal surface cleanliness is essential for adhesion of the coating to the substrate. Coatings applied over rust, dirt, or oil bond poorly to the substrate, and then the early coating failure usually will result unless the substrate is free from these contaminants.

Abrasive blast cleaning is perhaps the most productive method of surface preparation for coatings that require both an anchor pattern and a high degree of surface cleanliness. Blast cleaning is the only method that can completely remove intact rust and mill scale and produce an even roughness with a controlled anchor pattern. Abrasive blast cleaning is the propelling of abrasive materials at speeds of up to 724 km/h (450 miles per hour "mph") against a blasted surface.

The mass of abrasive, combined with velocity created by the compressed air 90 to 100 psi (620 to 689 kPa) used to propel the abrasive, creates kinetic energy. This kinetic energy is transferred to the surface and results in efficient removal of rust, mill scale, paint debris, and other surface materials. Simultaneously, a controlled surface profile is generated (PDGengineer.com, 1996).

Throughout history, humans have used as abrasives everything from sand, garnet and metallic shot/grit. This study covers some of the most widely used of naturally occurring abrasives including garnet, sand, flint, emery, ilmenite, and zircon. These materials may have varying characteristics and chemical compositions depending on the specific geological source (Bridge construction manual, 2008).

NONMETALLIC ABRASIVE MATERIALS

In the present study, a total of 40 collected samples from naturally occurring ores used as blasting abrasive materials were collected from Egypt, Indian, China and Austria as shown in Figure 1.

Garnet is a mineral abrasive produced from naturally occurring almandite garnet. The general chemical formula for garnet is A_3B_2 $(SiO4_4)_3$, where A can be calcium, magnesium, ferrous iron, or manganese; and B usually is aluminum, chromium, or ferric iron. The United States produces at least one-quarter of the industrial garnet mined worldwide; Australia reportedly is the only country that exceeds U.S. output, according to a survey conducted by the U.S. Geological Survey (USGS). It is produced by processing beach sand and grading to exact specifications. Due to its low free silica, garnet abrasive is

Table 2. Physical properties required for blasting abrasive media.

Abrasive property	Requirement	Standard
Particle size	Fine, medium, coarse	ISO 11127- 2
Apparent density kg/m^3	4.0 to 4.2	ISO 11127- 3
Mohs hardness	Min. 6	ISO 11127- 4
Moisture content %	Max. 0.2	ISO 11127- 5
Conductivity mS/m	Max. 25	ISO 1127- 6
Water soluble chloride %	Max. 0.0025	ISO 11127- 7

widely used in sand/grit blasting and now widely popular for water jet cutting. Garnet is cost effective, environmentally and operator friendly, alternative to silica sands and minerals slags and will provide a class Sa3 White Metal surface finish. Garnet particles are dense, hard and sharp and free of heavy metals or toxic components. The low friability of garnet permits recycling up to 5 times and the relatively high density ensures fast blasting speeds (www.indiamart.com).

The United States is the world's largest consumer of industrial garnet, accounting for 25% to 35% of global consumption as per Ronald (1997); the consumption of industrial garnet in U.S. was estimated about 65,000 tons in 1997. Garnet occurs worldwide in many rock types, principally gneisses and schists, other sources include contact metamorphic rocks, crystalline limestone, pegmatite, and serpentinites. Additionally, garnet is found near veins formed at high temperatures. Alluvial garnet is associated with heavy mineral sand and gravel deposits in many parts of the world.

In addition to the United States, significant quantities of industrial grade garnet are mined in several countries abroad. The most significant foreign producers are Australia, India, and China; other producers include the Czech Republic, Pakistan, Russia, Turkey, and the Ukraine. Estimates of total output by all producers worldwide range from 180,000 tons to 250,000 tons, but probably is not much greater than 200,000 tons. Total global supply is roughly divided among markets as follows: blasting media, 45%; water filtration, 25%; abrasive powders, 10%; water jet cutting, 10%; and other uses, 10%.

Sand, still used as blasting abrasive media in the Middle East, produces high levels of dust and contains high level of contaminants such as chloride. It generally does not produce a good surface profile as other abrasives. More importantly, its use is banned in most industrial countries due to its connection with silicosis, a lung disease caused by inhaling dust that contains silica, which is found in high level in sand. Sand is found in huge quantities in Egypt and the studied samples were collected from Ismailia and Salhyea which has a good reserve utilized by private sector for construction projects.

White sand, Zafarana white silica ore reserves are huge, and exceed billions of tons and the deposit has little or no overburden, and it is exposed in extensive areas. Many active quarries operated by public and private sector firms are operating in Abu Darag and Wadi Dakhal near Zafarana on the Red Sea coast. The sand mainly composed of SiO_2 ranging from 99.2 to 99.5% (Gaber, 2012).

Ilmenite ore occurs with huge reserve in Wadi Abu Ghalaga in the southern part of the Eastern Desert; the area comprises the Eastern portion of Hamata sheet, 30 km of Red Sea and 100 km south Marsa Alam. The ore deposits of Wadi Abu Ghalaga include two main parts, the eastern part composed of metavolcanics and the western part composed of ilmenite deposit surrounded by gabbroic rocks, the specific gravity ranging from 3.8 to 4.4 gm/cm^3 (Mahmoud, 2011).

Ilmenite grains were found on the Al Aresh Beach and Rashied area along sea coast in black sand, meanwhile the Egyptian Nuclear Materials Authority separates the grains of ilmenite and garnet to be utilized in industrial work.

EXPERIMENTAL

Forty samples of blasting abrasive nonmetallic ores were collected from different brand names and subjected to many tests to assess the physical and chemical properties comparing with standard of metal surface preparation requirements as shown in Tables 2 and 3.

Chemical analysis

The chemical analysis for different abrasive media includes sand, garnet, ilmenite and white sand which were carried out to determine the major constituents that affect the hardness and specific gravity. It was also done to check the presence of detrimental matters and corrosion constituents and adhesion impairing contaminants.

Physical properties

There are many physical properties characterizing the blasting abrasive media to achieve the required surface preparation of metallic surface. However, the standard state of the range of physical properties is illustrated Tables 2 and 3.

Table 3. Physical properties standard of natural ores used as abrasive media (Steel Structures Painting Council (SSPC), volume 1, 2003).

Variable	Hardness	Shape	Specific gravity	Free silica	Degree of dust	Reuse
Sand silica	5	Rounded	2-3	90 +	High	Poor
Sand heavy mineral	5 – 7	Rounded	3-4	< 5	medium	Good
Flint	6.5-7	Angular	2-3	90 +	medium	Good
Garnet	7 – 8	Angular	4	Nil	Low	Good 5
Ilmenite	7	Angular	4.4	< 30	medium	Good
Zircon	7.5	Cubic	4.5	Nil	Low	Good

Particle size distribution

Grain size distribution plays an important role in the use of blasting abrasive grains as an abrasive media to clean the rusted steel surface as per B.S 410 – 2 (2000). The mechanical analysis was carried out by sieving method with different screen sizes as per ISO 11127-2 (1993) and Gamal et al. (2012).

Moisture content

Moisture content is a concern from the standpoint of both production and quality. Abrasive with moisture content that exceeds the recommended levels tends not to have a uniform flow rate. In addition, flash rusting can result from the damp particles hitting the substrate. The SSPC abrasive specification recommends that the maximum moisture content be 0.5% by weight when tested in accordance with ASTM -C- 566 (1997) and ISO 11127-5 (1993).

Free flow

A minimum of 99% of the abrasive material shall flow freely from the test cylinder, with no apparent solidification or clump formation and shall be determined using these tools (bronze cylinder, balance, oven). The procedure to determine the free flow is as follows:

- Weigh a 50 gram of abrasive into the bronze cylinder with the solid cap on the bottom end.
- Fill the cylinder with water and allow the abrasive to soak for 1 h.
- Screw the hole bearing cap onto the top end of the cylinder, invert, remove the solid cap and allow the water to drain through the holes.
- Place the cylinder in horizontal position in an oven at 120°C for 3 h, then cool to room temperature and inclined the cylinder to an angle of 75°C, so the abrasive can flow freely by gravity. The abrasive shall be collected and weighed to determine compliance with the original weight (Military specification, 1997).

Conductivity

The conductivity shall be less than 290 micro Siemens per square centimeter (micromhos/cm) as per Military specification (1993), and shall be less than 150 uS/cm² as per Petroleum companies painting specifications and shall be measured in accordance to ASTM –D- 4940 (1998) and ISO 11127-6 (1993).

Oil content

The oil content in the abrasive material shall be less than 0.030% by weight.

Hardness

The blasting abrasive material shall have a minimum hardness of 6 on Mohs scale as per ISO 11127- 4 (1993).

Specific gravity

The minimum specific gravity of the nonmetallic abrasive material shall be 2.5 and shall be determined in accordance to ASTM –C- 128 (2001).

Shape

The abrasive material shall be uniform and angular to sub angular in shape by examining the abrasive material under a low power microscope (10×). A minimum of eighty percent of grains shall be angular in shape demonstrating the ability to cut the surface and create profile.

FIELD MECHANICAL TESTING

The field practical application and testing of different types of nonmetallic ores utilized as blasting abrasive media for surface preparation and cleaning before applying protective coating for metallic surfaces were conducted in PETROJET, Maidda yard and L&T Yard, Oman, to evaluate the suitability and performance of many types of abrasive media. The following tests were carried out as per international standard ASTM, B.S, ISO, SSPC and oil company specifications ADMA-OPCO, SHELL, TOTAL FINA ELF, and AGIP as follows:

Measurement of rust grade of metal surfaces

Rust grades of bare pipes are divided into 4 grades (A, B,

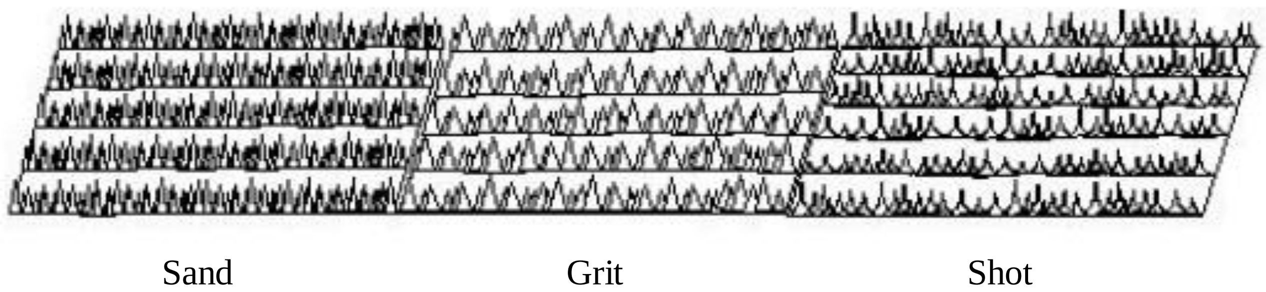
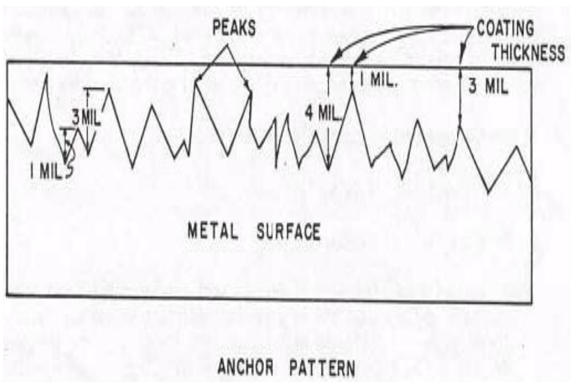


Figure 2. Photos showing the difference in profile between nonmetallic and metallic abrasive on metal surface of sand, grit and shot.



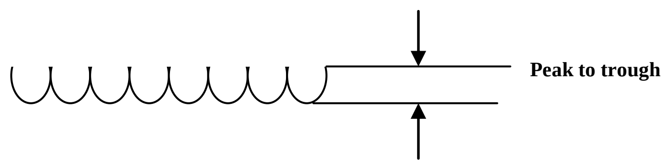


Figure 3. Profile peak and trough.

C, D) according to the degree of pitting in steel surfaces. The grade of the rust needs to be defined before starting surface preparation to determine the blasting method that can be used to achieve the cleanliness and profile degrees.

Surface cleanliness degree

The cleanliness degree achieved by blasting shall be at least Sa 2½ according to ISO 8501-1 (1988). Surface cleanliness involves determining how much of the original mill scale, rust and paint have been removed from the surface as well as how much invisible surface contamination is present usually in the form of salts.

Surface preparation is probably the main cause of most paint failures because more than any other factor, it affects how well the paint sticks to the surface being painted.

Surface profile

The surface anchor is necessary for good bonding of steel surfaces and coating materials and shall be measured according to ISO 8503-2 (1998). Surface profile is the determination of the roughness of the surface; however, for painting purposes, it involves depth of the profile, peak density and angularity of the profile as shown in Figures 2 and 3, and Table 4.

Most paint forms a mechanical bond with the steel, and generally surfaces that have roughness will supply the best mechanical bonds. Also, when you put a profile on the surface, you increase the surface area, so the paint has more surface area to adhere to. Different paints are made for different texture surfaces from smooth to rough.

There are currently four accepted ways to find surface profile and each one has advantages and disadvantages. The first three methods are detailed in ASTM –D- 4417 (1993) “Standard Test Method for Field Measurement of Surface Profile of Blast Cleaned Steel”:

1. Surface Profile Visual Comparator (D4417 Method A).
2. Surface Profile Gage - Profilometer (D4417 Method B).
3. Press-o-film Testex® Tape (D4417 Method C).

In this study, the Testex Tape method (D4417) is probably the most common method used to determine surface profile. The tape has a compressible foam layer with a 2 mil (50 um) Mylar covering. The foam takes on the shape of the profile and is measured with a spring micrometer. Since the foam is covered with 2 mils of

Table 4. Typical surface profile of some nonmetallic abrasive media (Steel Structures painting Council (SSPC), volume 1, 2003).

Abrasive media	Maximum U.S sieve size	Average profile (mils)	Average profile (um)
Garnet	30/60	1.97 - 2.95	50 - 75
	20/60	1.97 - 3.54	50 - 90
	20/40	2.95 - 3.93	75 - 100
	12/40	3.93 - 5.90	100 - 150
Heavy mineral sand	Medium-fine	2.6 - 2.1	66 - 53.4
Silica sand	Medium	2.9	74
Flint shot	Medium -fine	2.7	68.6
Ilmenite	Medium	2.9	74

Table 5. Comparison of salt level from wet and dry surface cleaning methods (ISO 8501-1, 1998).

Method	Remaining salt (ug/cm^2)	% Extracted
Wet blasting	0 – 2.4	Avg.*: 96.2%
Water jetting (35 Ksi)	0 – 2.4	Avg.*: 95.9%
Hand tool (SP2)	160 – 288	Avg.*: 43.8%
Power tool (SP 3)	212 – 296	Avg.*: 35.4%
Blast (SP 6)	44 – 68	Avg.*: 83.0%
UHP water jet	1.6 – 1.8	Avg.: 93.5%
Blast (SP 10)	3.3	84%
Needle gun	11.4	3%
Wire brush (SP 2)	15.2	9%
Blast (SP 5)	<3.2 – 3.4	Avg.: 90.2%
Power tool (SP 3)	16.2 – 24.1	Avg.: 43.5%
SP 3 + steam	8.6 – 12.9	Avg.: 69.9%
Power tool (SP 11)	7.0 – 13.9	Avg.: 72.1%
SP 11 + steam	3.9 – 7.7	Avg.: 84.5%
Power tool (SP 3)	22 – 97	Avg.: 45.4%
Power tool (SP 11)	41 – 124	Avg.: 17.2%

Mylar, this must be subtracted from the reading to get the surface profile (Tom, 1960).

Salt level

Chloride comes from the abrasive itself and may be transferred to the structure surface. Over a period of time, moisture drawn through the coating to the area containing the chloride may produce blistering and premature coating failure (Gay-lynne and Larry, 1989) as shown in Table 5 and Figures 4 and 5.

The coated surface shall be free of all hazard materials "salt level" and shall be tested according to ISO 8502-6 (1995).

Dust level

Dust level for coated surfaces shall be less than rate 2 as per coating specifications of ISO 8502-3 (1992).

Abrasive conductivity

The soluble salts such as sulfate or nitrate are considered less detrimental to steel surface than chloride; therefore, if the conductivity comes primarily from sulfate, the allowable level of conductivity would be much greater than that for chloride. For example, the water jetting standard SSPC-SP12/NACE 5, level SC-2 cleaning has an allowable chloride level of 7 ug/cm^2 and an allowable sulfate level of 17 ug/cm^2 (JPCL, January, 2008). The conductivity measurement is necessary before starting surface preparation to ensure the abrasive is free from detrimental material as shown in Figure 6.

Productivity rate

The productivity rate of abrasive media depends on hardness and specific gravity. The harder and heavier blasting abrasive will create an anchor profile and clean

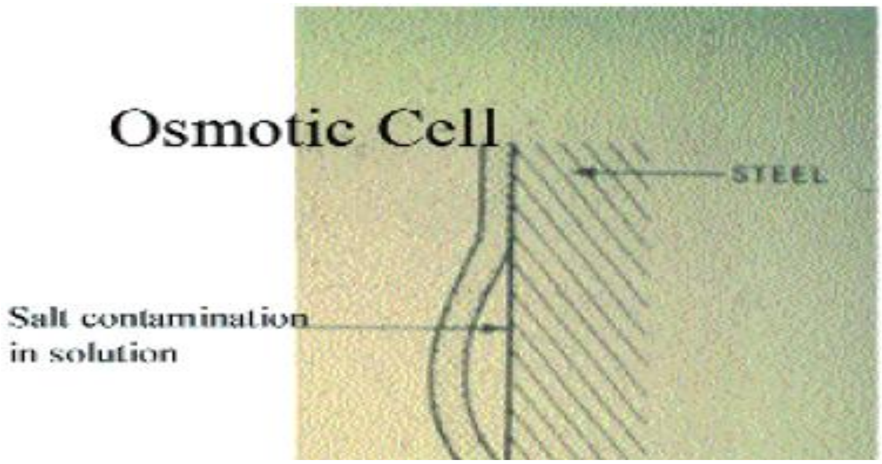


Figure 4. Schematic of development of osmotic cell.

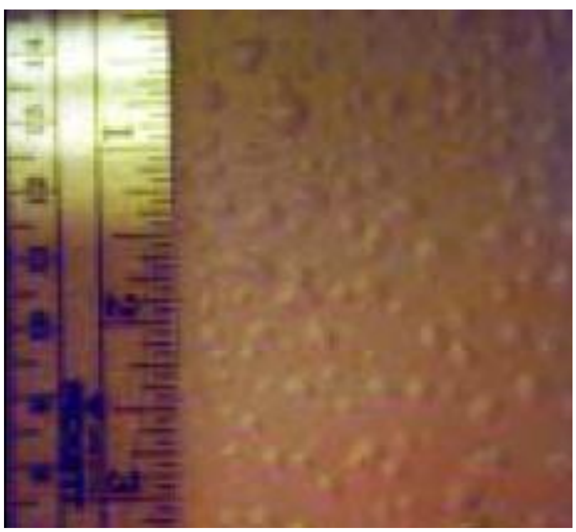


Figure 5. Osmotic blistering (JPCL, 2002).

Figure 6. Conductivity meter.

its surface, thereby significantly increasing productivity of surface preparation while reducing abrasive consumption. Tables 6 and 7 illustrate the figures for some abrasive media used for production rate per square meter (www.barton.com). The cost analysis of abrasive media is calculated as follows:

$$\text{Cost per square meter} = \frac{\text{flow rate (price per ton + disposal cost) + cost of equipment and labor}}{\text{production rate}}$$

A: Garnet $\frac{0.333 \times (300 + 10) + 50}{18.33} = \$\ 8.35\ m^2$

B: Sand $\frac{1.219 \times (15 + 10) + 50}{17.5} = \$\ 4.6\ m^2$

C: Coal Slag $\frac{0.600 \times (160 + 25) + 50}{15} = \$\ 10.73\ m^2$

Reuse

Abrasive materials are typically very hard and chemically stable; as such, while they can be disposed of, they will not break down like other materials like biodegradable plastics or even steel.

RESULTS AND DISCUSSION

Physical properties of abrasive media

The following tests were carried out on some nonmetallic blasting abrasive media produced in Egypt, India, China and Australia, and the following results were derived and illustrated in Tables 8 to 10.

Chemical analysis of abrasive media

Chemical analysis was conducted for sand, ilmenite,

Table 6. Cleaning rates and abrasive consumption of blasting abrasive media (Steel Structures Painting Council (SSPC), Volume 1, (2003).

Abrasive	Abrasive consumption	Production rate
Silica sand 16/40 mesh	12.69 kg/sqm (2.6 lb/sq ft)	0.44 sqm/min
Garnet 36 grit	17.58 kg/sqm (3.6 lb/sq ft)	0.33 sqm/min
Crushed flint 12/30 mesh	17.58 kg/sqm (3.6 lb/sq ft)	0.25 sqm/min
Ilmenite		
Staurolite 50/100	15.13 kg/sqm (3.1 lb/sq ft)	0.45 sqm/min
Aluminum oxide 36 grit	15.3 kg/sqm (3.1 lb/sq ft)	0.42 sqm/min
G-40 steel grit	26.86 kg/sqm (5.5 lb/sq ft)	0.28 sqm/min

Table 7. Application parameters and cost comparison of blast abrasive media (garnet, sand, coal slag) applied for new steel with light rust (PCE, May, 1989).

Variable	Garnet	Sand	Coal Slag
Abrasive consumed	50 kg	50 kg	50 kg
Grain size	0.2-0.6 mm	0.1-2 mm	0.25-1.45 mm
Hardness (Moh)	8	6.4	6.7
specific gravity	4	2	2
Blast standard	Sa3	Sa2½	Sa2½
Area blasted	2.75m^2	0.73 m^2	1.27m^2
Time taken	9 min	2.5 min	5 min
Air pressure	85 psi	85 psi	85 psi
Dusting	Very low	Very high	High
Profile	65 um	38 um	52 um
Production rate	18.33 m^2/h	17.5 m^2/h	15 m^2/h
Flow rate (kg/h)	333	1219	600
Price per tone	$300	$15	$160
Disposal cost	$10	$10	$25
Cost of equip. and labor/h	$50	$50	$50

white sand and garnet and the results are indicated in Table 11.

Field mechanical testing of blasting abrasive media

Rust grade of bare pipe before blasting

Rust grades of bare pipes are divided into 4 grades (A, B, C, D) according to the degree of pitting in steel surfaces. The rust grade of coated pipes used in this work is grade B which means that more or less presence of rust traces “pitting” start to appear as shown in Figure 7. The grade of rust needs to be defined before initiating the surface preparation to determine the blasting method that can be used to achieve the cleanliness and profile degrees.

Cleanliness degree

The cleanliness degree achieved by blasting is Sa 2½ to Sa3 according to ISO 8503-1 (1988) and is illustrated in Figure 8.

Surface profile

The surface profile, or depth that the abrasive digs into the surface, is affected by the abrasive size, hardness, and shape, and by distance from the blast nozzle to the surface (Gay-Iynne and Larry, 1989). The surface anchor is measured using the Press-O-Film gauge (Figures 9 and 10), and it is necessary for bonding of primer with steel surfaces and polyethylene coating layers, with the profile ranging from 65-80 um as per ISO 8503-2 (1998).

Salt contamination level

Recent investigations show that the main chlorides are critical to the performance of protective coatings, though small increase in salt content (+1ug/cm^2) heads to a

Table 8. Physical properties of Egyptian types of natural ores used as abrasive media.

Variable	Egyptian abrasive ores			
	Sand	**Garnet**	**Ilmenite**	**White sand**
Moisture content	0.03	0.00	0.00	0.01
Free flow	90%	95%	90%	95%
Conductivity (ms/m)	20	10 – 15	10 – 15	10
Oil content	None	None	None	None
Hardness (Mohs)	6	7 – 8	8	7
specific gravity	2.7	4.0 – 4.5	4.2	2.7
Grain shape	Rounded	Sub angular	Sub angular	Sub angular
Silica free	1.8	0.3 – 0.5	0.9	0.8

Table 9. Physical properties of imported garnet used as abrasive media.

Variable	Indian - GBA	Australia - GMA	China - Wuxi Ding
	Garnet	**Garnet**	**Garnet**
Moisture content	Non hygroscopic	Non hygroscopic	Non hygroscopic
Free Flow	90 %	95 %	90 %
Conductivity (ms/m)	10-15	10	10
Oil content	Free	Free	Free
Hardness	7 – 8	7 – 8	7 – 8
specific gravity	4 – 4.5	4.1	4 – 4.5
Grain shape	Sub angular	Sub angular	Sub angular
Silica free	0.5	0.4	0.5
Melting point	1260°C	1250°C	1260°C

Table 10. Average results of garnet sieve analysis for grade 30/60.

ASTM	MM	Standard %	Retained %	Cumulative %
30	0.6	1.2	0.48	0.48
40	0.425	28.5	31.1	31.58
50	0.3	53.2	57.86	89.44
60	0.25	14.6	8.24	97.68
80	0.18	2.5	2.32	100

Table 11. Chemical analyses of Egyptian natural ores used as abrasive media.

Ore type	Chemical composition							
	SiO_2	**Al_2O_3**	**FeO**	**CaO**	**MgO**	**MnO_2**	**Fe_2O_3**	**TiO_2**
Sand	99.30	0.00	0.15	0.35	0.20	0.00	0.00	0.00
Ilmenite	4.00	1.00	44.00	0.00	0.00	0.00	26.00	25.00
White sand	99.50	0.10	0,09	0.00	0.10	0.10	0.00	0.00
Garnet	39.25	19.46	32.41	2.88	5.74	0.13	0.030	0.01

200% decrease in coating lifetime (JPCL, February, 2004). Salt content is basically evaluated through the following three parameters: specific electric conductivity (us/cm), volumetric concentration (ppm = ug/cm^3), and surface concentration (ug/cm^2).

The coated surface shall be free of all hazard materials,

Figure 7. Rust grade B.

a b c d

Figure 8. Cleanliness degree achieved by blasting: (a) sand pots and compressor; (b) abrasive media; (c) blasting nozzle; and (d) blast clean surface.

Figure 9. Profile gauge and Press-O-Film.

Figure 10. Measuring profile.

Figure 11. Attachment of paper to substrate.

Figure 11. Attachment of paper to substrate.

the results of which indicate that the salt level measured using SCM 400 is 1 um/cm^2 "10 - 15 mg/m^2" as shown in Figures 11 and 12.

Dust level

Dust on blast cleaned steel surfaces may reduce the adhesion of applied coatings and by absorbing moisture may promote the corrosion of the blast cleaned steel. Assessing the quality of the dust on the tape is done by comparing visually an area of the tape with equivalent sized areas of the pictorial reference as shown in ISO 8502-3 (1992). The rust grade level is less than rate 2 as shown in Figure 13.

Abrasive conductivity

Physical and chemical analysis carried out for the abrasive material measured before usage in the blasting machine showed that the material is free from

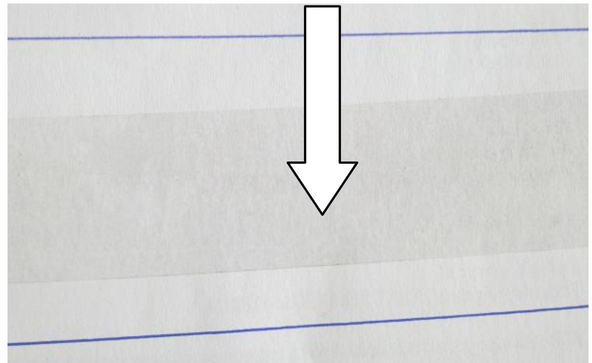


Figure 13. Transparent tape indicating no trace of contamination.

contamination and the conductivity ranged from 10 to 15 ms/m (100 - 150 uS/cm) thus complying with the coating specification requirements (Total Fina Elf, 2002).

Productivity rate

The field application indicates that surface preparations production rate of Egyptian garnet ranged from 15 to 18 m^2/h for rust grades A and B.

Reuse

The field testing indicates that the sand is used once, but the garnet types can be recycled due to its hardness and sharp fracture which help in removing the contamination dust by sieving or washing.

Conclusions

- Soluble salts, particularly chlorides, widely prevail in many industrial exposures where coatings are applied. If not removed prior to application of the coatings, the soluble salts can adversely affect coating lifetime, resulting in early degradation and failure. The most successful means of removing the salts is a combination of water and abrasive blasting.
- Garnet abrasive have many benefits, some of which are: lower dust level, high productivity, lower consumption, and high recycling ability.
- There is a huge reserve of sand with good quality for metal surface preparation located in Salhya and Ismailia areas.
- The laboratory testing and analysis proved that the local sand, garnet, ilmenite, and white sand can be utilized as blasting abrasive media to achieve the required surface preparation standards.
- Most of the studied ore deposits occur without waste capping, that is, “overburden”.
- The utilization of the local ores, as a substitute for the imported ores will save hard currency and promote the mining work in Egypt.

ACKNOWLEDGMENTS

The authors would like to express their profound gratitude to PETROJET painting crew at Maadia yard, and LARSEN and TOUBRO LIMITED (L&T), Oman, for helping to evaluate the abrasive media and conducting the practical and field testing.

REFERENCES

ASTM –C- 128 (2001). Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate1.

ASTM -C- 566 (1997). Standard test method for total evaporable moisture content of aggregate by drying.

ASTM –D- 4417 (1993). Standard test method for field measurement of surface profile of blast cleaned steel.

ASTM –D- 4940 (1998). Standard test method for conductimetric analysis of water soluble ionic contamination of blasting abrasives.

B.S 410 – 2 (2000): Test sieves. Technical requirements and testing “Test sieves of perforated metal plate”.

Barton data sheet: Technical data sheet and physical characteristics for Barton garnet abrasive, www.barton.com, page 9/14.

Bridge Construction Manual (2008). Kansa Department of Transportation, page 3.

Dev International abrasive data sheet, www.indiamart.com , Ahmedabad - 380004, Gujarat, India

Gaber MAW, (2012). Evaluation of some natural ores from Egyptian Eastern Desert to be utilized in producing of paint materials, Journal of Petroleum and Gas Exploration Research, Vol. 2(1) pp. 017-026.

Gamal El Din AI, Mousa AS, El-Hariri TM, Gaber MAW (2012). Utilization of Sodium silicate Solution as a curing compound of fresh concrete : Journal of American Science, 8 (11):61-66.

Gay-Iynne S, Larry B (1989). Abrasive selection: performance and quality considerations, page 2 and 5.
ISO 11127- 4 (1993). Preparation of steel substrates before application of paints and related products - Test methods for non-metallic blast-cleaning abrasives - Part 4: Assessment of hardness by a glass slide test.
ISO 11127-2 (1993). Preparation of steel substrates before application of paints and related products - Test methods for non-metallic blast-cleaning abrasives - Part 2: Determination of particle size distribution.
ISO 11127-5 (1993). Preparation of steel substrates before application of paints and related products - Test methods for non-metallic blast-cleaning abrasives - Part 5: Determination of moisture.
ISO 11127-6 (1993). Preparation of steel substrates before application of paints and related products - Test methods for non-metallic blast-cleaning abrasives - Part 6: Determination of water-soluble contaminants by conductivity measurement.
ISO 8501-1 (1998). Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.
ISO 8502-3 (1992). Preparation of steel substrates before application of paints and related Products - Tests for the assessment of surface cleanliness - Part 3:Assessment of dust on steel surfaces prepared for painting (pressure sensitive tape method).
ISO 8502-6 (1995). Preparation of steel substrates before application of paints and related products - Tests for the assessment of surface cleanliness - Part 6: Extraction of soluble contaminants for analysis - The Bresle method.
ISO 8503-1 (1988). Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates –Visual assessment of surface cleanliness.
ISO 8503-2 (1998). Preparation of steel substrates before application of paints and related products – surface roughness by comparator method.
JPCL, (2002). Advances in technology and standards for mitigating the effects of soluble salts, page 45.
JPCL, (2004). Surface preparation standards for steel substrates, February, page 51.
JPCL, (2008). On conductivity and chloride concentration , January, page 77.
Mahmoud IA,(2011): Mohamed Abd EL-Fattah Moustafa, Hany El- Sayed Ahmed, Hamada Abd El-Wahab : Utilization of Egyptian Ilmenite Ore for Steel Surface Preparation in Petroleum Field; Engineering,2011,3, page 804.
Military specification, (1993):MIL-A-22262B (SH): Abrasive blasting media.
Military specification, (1997): MIL-A-22262A (SH): Abrasive blasting media.
PCE, May, (1989) : Economics of abrasive selection for shipyard use, page 28.
PDGengineer.com (1996). Coating surface preparation, EM 1110-2-3400, Chapter 7,1996.
Ronald FB (1997). Garnet industrial, page 301.
Tom S (1960). East # 4: The Coating Inspectors Handbook, Page 18, 19, Humble, TX77338. 2115 FM,
Total Fina Elf, (2002). External protection of off-shore and related structures and equipment by painting, page 11.