Bulletin No. 44

भारत सरकार
GOVERNMENT OF INDIA
खान मंत्रालय
MINISTRY OF MINES
भारतीय खान ब्यूरो
INDIAN BUREAU OF MINES

Bulletin on Abrasives in India

NAGPUR

June, 2005

Bulletin No. 44

Government of India
Ministry of Mines
INDIAN BUREAU OF MINES

Bulletin

on

ABRASIVES IN INDIA

Issued by
CONTROLLER GENERAL
INDIAN BUREAU OF MINES, NAGPUR

Prepared by
Mineral Economics Division

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Preface

"Abrasives in India" is the 44th in the series of Bulletins brought out by Indian Bureau of Mines on various topics embracing minerals and mineral products.

Abrasives are natural or manufactured substances which are used to abrade, clean, etch, grind, polish, scour or to remove unwanted solid material by rubbing or impact; as such abrasives play an important role in fashioning and finishing numerous products which have wide range of end-use applications.

The important physical properties the abrasives should possess are hardness, toughness, friability, grain size, grain shape, and high degree of purity. Besides, it should withstand heat and should have strong bonding affinity.

The natural abrasives include bauxite, corundum, diatomite, diamond, emery, feldspar, garnet, perlite, etc. whereas the manufactured abrasives include carborundum, fused aluminium oxide, silicon carbide and boron carbide. The demand and consumption of manufactured abrasives are much more than those of natural abrasives because the manufactured abrasives meet the requirements of industries which is attributed to its required uniform quality. In other words, though the manufactured abrasives are costlier than natural abrasives, the industry prefers manufactured abrasives because of its quality, durability & usefulness to get the fashioned and finished product of required specification.

The abrasives are used in three basic forms, viz. loose, granular, and powdered forms. Abrasives are bonded in the form of sheets, wheels, bars, rings discs, sticks, etc. using glue or synthetic resins as binding agents. The coated abrasives are prepared using paper or cloth or rubber as foundation material over which abrasives are bonded using binding material.

The various abrasive producing units mostly use minerals like bauxite, feldspar, diatomite, garnet, perlite, etc. in different forms or by mixing with non-reactive chemical agents to manufacture coated abrasives. The authentic and systematic data regarding manufactured abrasives produced in India is not available; however, data collected from various sources reveals that about 3,670 and 3,920 tonnes of abrasives were manufactured in the country during the year 1999-2000 and 2000-01, respectively.

This bulletin gives information on various types of abrasives, prospecting, occurrences, reserves, specifications required for consuming industries, methods of extraction, abrasive-based industries in India, etc. It is hoped that this bulletin will be useful to technicians, industrialists, academicians and all those who are dealing with the abrasives.

Shekhar

S. S. DAS
Controller General
Indian Bureau of Mines

Nagpur
Dated : 14.8.2004

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CHAPTER 1

Introduction

Abrasives in one or other form have been used for over two million years. The first crude wooden tools were made by rubbing them to shape or sharpen against sandstone or flint. There are three basic forms in which abrasives are used - loose, granular and powdered particles. Abrasives in which particles are bonded with various agents into wheel, segmental or stick shapes and particles deposited with glue or synthetic resins on paper or cloth are known as coated abrasives. Abrasives include the substances, natural or artificial, that are used to grind, polish, clean or remove solid material, usually by rubbing action and also by impact, e.g. pressure blasting. They do not include abrasive tools, for instance, lathe tools and files or polishing agents, such as waxes, which act by filling pores. Action of detergents and cleaners is chemical rather than physical. Such chemical reactions are omitted although some chemical action may impart polish and cleaners may also contain solid abrasives, for example, many automobile and metal polishes.

The most important physical properties of materials that qualify them for use as abrasives are hardness, toughness (or brittleness), grain shape and size, character of fracture or cleavage and purity or uniformity. For making bonded-abrasive products, such as grinding wheels, additional important factors are stability under high heat and bonding characteristics of grain surfaces. The economic factors like cost and availability are also important.

No single property is paramount for any use. For some uses, extreme hardness and toughness are needed, as in diamonds for drill bits. For others, the factors of greatest importance are hardness and ability to break down slowly under use to develop fresh cutting edges when grains become worn, for example in garnet for sandpaper, neither highly cleavable nor friable grains nor extremely tough grains are required. For still other uses, more hardness is objectionable, for example, abrasives for glass cleaning soaps. For the most efficient use in more critical applications, the different types of abrasives are rarely interchangeable. Thus, while both crushed quartz and garnet are used in sandpapers, the papers are not at all interchangeable in their applications.

The choice of a high grade abrasive depends upon the quality and quantity of work done by the abrasives per unit cost. Initial cost of an artificial abrasive may be much more than that of a natural abrasive but the artificial abrasive may do much better and faster work than the natural one, so that the ultimate cost is less. It is for this reason, the artificial abrasives have replaced largely the natural abrasives.

Abrasives may be divided into two general classes, natural and manufactured. The former includes all rocks and minerals used for abrasive purposes without chemical or physical change other than crushing, shaping or bonding into suitable forms. Manufactured or artificial abrasives are made either by heat or chemical action on metals or mineral raw materials. For most types of uses, manufactured products that can be substituted for the natural products, usually at higher initial cost but with higher efficiency. This is not always true, for example, there is no satisfactory manufactured substitute for garnet for making coated abrasive paper and cloth. For some abrasives the use of which is gradually declining, the making of manufactured substitutes has not been economically attractive. However, even for such a low-priced commodity as pressure blasting sand, there are substitutes, such as steel shot, fused aluminum oxide and silicon carbide grains. The decline in the use of most natural abrasives and their replacement by manufactured abrasives have not been responsible for a net loss to the mineral industry because all manufactured abrasives are made from mineral raw materials.

Synthetic diamond (manufactured) using high pressure and high temperature methods compete with natural industrial diamonds as an abrasive mineral, silicon carbide (SiC), alumina (Al_2O_3), tungsten carbide (WC) and carbon-boron nitrate (CBN) as manufactured material. A very popular type of synthetic diamond is called "Synthetic Diamond Abrasive" (SDA).

Abrasive products may be divided broadly into the following types:

a) Abrasive grains and powders which are loose
b) Abrasive grains bonded into wheels, blocks, and special shapes
c) Coated abrasive grains bonded to paper and cloth
d) Abrasive grains and powders in paste form
e) Abrasive grains and powders, brick and stick forms, grease, glue and wax binders
f) Natural rocks shaped into sharpening stones, such as oilstones, razor hones, etc.
g) Natural stones shaped into rubbing and polishing stones, such as holystones and pumice scouring blocks
h) Natural stones shaped into blocks for pebble-mill liners
i) Pebbles, natural and manufactured, for grinding mills

CHAPTER 2

Types of Abrasives, Abrasive Products and their Prospects

2.1 TYPES OF ABRASIVES

Abrasives include the substances, natural or artificial that are used to grind, polish, abrade, scour, clean or otherwise remove solid material, usually by rubbing action and impact, e.g. pressure blasting. These do not include abrasive tools, for instance, lathe tools and files or polishing agents, such as waxes, which act by filling pores. Detergent and cleaners the action of which is chemical rather than physical are omitted. The most important physical properties of materials that qualify them for use as abrasives are hardness, toughness (or brittleness), grain shape and size, character of fracture or cleavage and purity or uniformity. For making bonded-abrasive products, such as grinding wheels, additional important factors are stability under high heat and bonding characteristics of grain surfaces. The economic factors like cost and availability are always important. Therefore, abrasives cover everything from crushed plum stones and polystyrene balls to silicon carbide and diamonds. It even includes water if applied under sufficient pressure. The breadth of the term abrasive may be judged by the fact that talc as well as diamond are sometimes utilised for their abrasive qualities. No single abrasive is all-purpose; the choice depends on which abrasive will perform the job most efficiently and economically. Physical properties are of paramount importance in an abrasive, particularly hardness and toughness. These properties are by no means synonymous, although often they are interdependent, one decreasing as the other increasing [1,2]

Abrasive action is measured by comparing two abrasive substances. Abrasiveness can be defined by four properties; hardness, toughness, degree of chemical inertness and in some instances, resistance to heat. An optimum combination of each property would define the ultimate abrasive although in practice, less than optimum combinations are sometimes more desirable. The earliest scale of hardness still in extensive use was introduced by Fredric Mohs, a German mineralogist, about

Table 2.1: Scale of Hardness

Mineral	Mohs' scale	Ridgway's extension of Mohs' scale	Hardness
Talc	1		
Gypsum	2		
Calcite	3	Orthoclase, periclase	6
Fluorite	4	Vitreous pure silica	7
Apatite	5	Quartz	8
Feldspar (orthoclase)	6	Topaz	9
Quartz	7	Garnet	10
Topaz	8	Fused zirconia	11
Corundum	9	Fused alumina	12
Aluminum oxide	9	Silicon carbide	13
Silicon carbide	9.50	Boron carbide	14
Boron carbide	9.75	Diamond	15
Borazon (boron nitride)	10		
Diamond	10		

one century ago. It is based on the relative hardness of minerals, the one which scratches or marks another being considered the harder. Mohs' scale of increasing hardness from 1 to 10 furnished in Table 2.1 is unsatisfactory for modern abrasives because it is not linear, i.e. a hardness of 2 is not twice the hardness of 1, a hardness of 9 is not three times the hardness of 3, etc. In addition, most satisfactory abrasives lie between 9 and 10 and they are not easily differentiated by the scale. The Knoop scale of hardness furnished in Table 2.1 (a) is the most widely used for very hard materials. It is based on resistance to penetration by diamond. The resistance is measured by the length of the indentation and the load required to produce it.

Table 2.1 (a)
Knoop Scale of Hardness
(Numbers, at a 100 g load (K-100) average, kg/mm^2)

Quartz	820
Topaz	1350
Corundum	2000
Fused alumina	2050
Silicon carbide	2500
Boron carbide	2800
Borazon (boron nitride)	4700
Diamond	8350

(Boron carbide, borazon, silicon carbide, and aluminum oxide are manufactured abrasives. Borazon and boron carbide are relatively recent developments and the above hardness ratings are subject to some differences of opinion and differing laboratory test results.)

Factors governing the accuracy of the measurement are crystal chipping, crystal orientation, amount of load, and rate of load application and operator interpretation.

Toughness is defined as the ability of an abrasive to withstand the forces brought to bear upon it when in use. Specific applications often require variable toughness in a single abrasive material so that an abrading operation may be performed properly. The toughness of abrasives may vary chemically. The measurement of toughness is generally performed by ball milling or by shooting the abrasive grains against a barrier. In either case, the degree to which the particles are broken down or reduced in size is inversely proportional to their toughness. Grinding tests have correlated well with toughness tests performed in this manner.

Any chemical activity existing between the abrasive and the abraded article will be greatly accelerated at the point of abrasion because heat is usually generated during abrasion. Generally the best abrasive for a given operation is the one that is most nearly inert to the material to be ground. However, in most loose abrasive applications, the heat generated is insufficient for observed chemical activity.

2.2 CLASSIFICATION OF ABRASIVES

The abrasive materials are either natural or manufactured. These consist of granular particles classified by a numerical size scale commonly called grits or grains. Each particle is a cutting, grinding or polished tool that does the actual work in any abrasive process. They are used loose, bonded with inorganic or organic bonding materials into wheel, segment or stick shapes or as coated abrasives deposited in a relatively thin layer with glue or synthetic resins as a binder on paper or cloth. A cubic centimetre of a bonded shape may include thousands and a square centimetre of coated

abrasive may contain hundreds of abrasive particles. Natural abrasives include all rocks and minerals used for abrasive purposes without chemical or physical change other than crushing, shaping or bonding into suitable forms. Manufactured or artificial abrasives are made either by heat or chemical action from metals or mineral raw materials. For most types of uses, the manufactured products can be substituted for the natural products, usually at higher initial cost but with higher efficiency. This is not always true, for example, there is no satisfactory manufactured substitute for garnet for making coated-abrasive paper and cloth. Table 2.2 provides classification of abrasives. The decline in the use of most natural abrasives and their replacement by manufactured abrasives have not been responsible for a net loss to the mineral industry. However, all manufactured abrasives are made from mineral raw materials [1,3].

Table - 2. 2 : Classification of Abrasives

Natural Abrasives
Superior Hardness (above 7 in Mohs' scale)

Diamond	- H-10
Corundum	- H-9
Emery	- H-7 to 9
Garnet	- H-6.5 to 7.5
Staurolite	- H-7.0 to 7.5

Intermediate Hardness (H-5.5 to 7)
Silica Abrasives
Buhrstone
Chalcedony
Chert
Flint
Novaculite
Quartz
Quartzite
Sandstone
Silica sand

Other Rocks and Minerals
Argillaceous limestone
Feldspar
Perlite
Pumice and pumicite
Quartz conglomerate

Inferior Hardness (H-under 5.5)
Apatite
Calcite
Chalk
Clay
Diatomite
Dolomite
Iron oxides
Limestone
Rottenstone
Siliceous shale
Silt
Talc
Tripoli

Boron carbide	Manganese dioxide
Boron nitride	Periclase (art.)
Calcium carbonate (ppt.)	Silicon carbide
Calcium phosphate	Tantalum carbide
Cerium oxide	Tin oxide
Chromium oxide	Titanium carbide
Clay (hard burned)	Tungsten carbide
Diamond	Zirconium oxide
Fused alumina	Zirconium silicate
Glass	Metallic abrasives
Iron oxide	Metallic abrasives-steel wool, steel shot, angular steel grit, brass wool, copper wool, porcelain blocks for mill liners and grinding pebbles
Lime	
Magnesia (ppt.)	

2.3 NATURAL ABRASIVES

Natural Abrasives are described in detail in Chapter 4.

2.4 MANUFACTURED (ARTIFICIAL) ABRASIVES

The discovery of the electric furnace method for making silicon carbide began the revolution in the high-grade abrasives industry. Prior to that time, all abrasives were natural minerals and rocks, except for minor chemically prepared materials. Today, artificial abrasives, with a few notable exceptions, such as diamond and garnet, dominate if not monopolize the field of high-grade abrasives. Manufactured abrasives are essential to modern industry because they are not only superior to natural abrasives but also much more uniform in quality and their properties can be varied to meet difficult needs.

Manufactured abrasives may be divided into three main groups:

(a) Electric furnace products
(b) Chemical precipitates
(c) Several miscellaneous additions

Electric furnace abrasives include silicon carbide, aluminium oxide and boron carbide. Tungsten carbide, tantalum and titanium carbides are used in making cemented carbide high-speed cutting tools but are not considered as abrasives in customary usage.

Silicon Carbide : Silicon carbide, chemical formula SiC, is commonly known by the trade names carborundum, crystolon and carbolon. It is made by fusing a mixture of high-grade silica sand and carbon in an electric furnace. The preferable form of carbon used today is petroleum coke but anthracite and coke made from coal low in ash have been used. Silicon carbide is made by charging a resistance-type electric furnace with pure glass sand, finely ground petroleum coke, sawdust and common salt. The silicon of the sand combines with the coke (carbon) to form silicon carbide. The sawdust makes the mixture porous so that carbon monoxide gas formed in the course of the chemical reaction can escape freely.

Fused Aluminium Oxide : Aluminium oxide abrasives are made in electric-arc furnaces. Bauxite is the crude raw material. The ore as mined is crushed and then calcined in rotary kilns to remove both free and combined water. The calcined ore is mixed with iron (about 2%) and ground coke (about 3%) and charged into the furnace. The coke reduces the impurities which combine with the iron and sink

to the bottom of the furnace. At the end of the melting period, the charge is allowed to cool under controlled conditions to obtain desired texture. Two heavy-duty abrasives are (i) an electric furnace fusion product made up primarily or an intimately crystallised mixture of aluminum oxide and zirconia and (ii) a sintered product.

Boron Carbide : Boron carbide is an artificial abrasive. Its chemical formula is B_4C. It is made from boric oxide (B_2O_3) and carbon in the form of petroleum coke in a carbon-resistance furnace at a temperature of about 2600°C. The finished product is crushed and ground to make a range of sizes of grains and powders. In grain form, it is used for grinding and lapping operations for jobs previously possible with diamond dust.

Boron Nitride : Boron nitride in cubic form is a new manufactured abrasive discovered by General Electric Company. It is made at temperatures and pressures comparable to those required for diamond manufacture.

Tungsten Carbide : Tungsten carbide is classed as a cutting medium rather than as an abrasive. The almost universal use of tungsten carbide tip on bits has revolutionised drilling blastholes in mining and quarrying operations.

Manufactured Diamond: General Electric Company has first succeeded in producing diamond in the laboratory from carbonaceous material subjected to a high pressure at a very high temperature for prolonged periods. Crystals up to 1.6 mm (1/16 inch) long were made in 16 hr but smaller ones were produced in much shorter times. The high pressure is capable of maintaining temperatures above 2760°C (5000°F). Costs were reported to be about twice the comparable natural diamonds and sizes were small, nevertheless economical commercial production was anticipated. The diamonds so far made have not been of gem quality.

Metallic Abrasives : Metallic abrasives include crushed steel, steel shot, angular steel grit, steel wool, brass wool and copper wool.

Chemical Precipitates : Chemical precipitates, mainly oxides, have a very fine grain size and are used as final polishing agents. The chemical precipitates products are crocus, black rouge, tin oxide, cerium oxide, manganese dioxide, magnesia, calcium carbonate and calcium oxide.

2.4.1 Miscellaneous Manufactured Abrasives

Glass and screens have been used for coated abrasives to make black glasspaper known as 'satin rough'which finds some use for polishing celluloid and bone clay. A very hard burned and finely pulverized material has been reportedly used as an abrasive for polishing metal.

2.5 ABRASIVE PRODUCTS

Bonded abrasives come in a variety of forms including wheels, discs and sticks formed using various grains. These are often subdivided into grinding, polishing, etc. A variety of bonds are also used including resin, elastometric, vitrified and metallic, each giving different performance characteristics. For example, resin-bonded wheels are more resistant to stock loading and heavy use than vitrified-bonded wheels. In addition to the development of abrasive grains, companies that produce abrasive products innovate to generate enhanced performance. For example, research work on abrasive has developed abrasive wheels with aluminium oxide and silicon carbide bonded with plastic in a proprietary process. Such wheels are found five or six times more efficient and economical than conventional grinding wheels. Increasingly, manufacturers of abrasive products are working closer to their customers to develop products that more precisely meet their needs. Companies are addressing the value function and paying closer attention to what a product will do for their operations. A more expensive product may be worthwhile due to less rejection rate[3]

Loose Abrasive Grains : Abrasive grains are produced from a wide variety of materials, both for use as grains and for incorporation into other products. Thus, abrasive grains are not only important products themselves but are the starting point for making bonded shapes, coated abrasives, abrasive tools, polishes, cleaners, grinding pastes and compounds. For pressure blasting, in addition to silica sand, other natural mineral grains are used, such as corundum, garnet, flint and chert as well as manufactured products, such as fused alumina, silicon carbide, and steel shot. The physical properties like toughness, grain shape, grain size, uniformity and specific gravity are important. Grains should be tough so that they will not disintegrate readily under impact during some uses. Rounded grains are considered desirable and sharp cutting edges are favoured. Uniformity of grain size and other physical properties are always desired. The higher the specific gravity, the greater is the force of impact for grains of equal size. Each use has its own special requirements.

Loose grains of relatively coarse sizes are used for sawing stone, rough grinding plate glass and surfacing stone. Materials used are quartz sand, garnet, corundum, emery, aluminum oxide and silicon carbide.

Grains of somewhat smaller sizes of the same material are used for grinding lenses, rough polishing of building stone and plate glass, rough polishing of gems & ornamental stones and dressing & polishing wood surfaces.

Fine-grained powders are used for polishing and lapping of a variety of materials including glass, building and decorative stones, metals, plastics, tiles and artificial stone flooring, gems & semi-precious stones and wood surfaces. The abrasive materials used are tin oxide, aluminium oxide, chromium oxide, cerium oxide, diamond dust, feldspar, garnet, pumice, diatomite, ground silica and clay and zirconium oxide. Many automobile body cleaners and polishes contain diatomite. Abrasive grains, closely sized are bonded and pressed or moulded into a wide variety of bonded abrasives, such as grinding wheels. There are five main types of bonded abrasives depending on the type of bond and method of manufacture : (1) Vitrified wheels with a clay feldspar bond is vitrified in ceramic kilns. (2) Resinoid wheels with a hard synthetic resin bond are high-speed wheels used in foundries, welding, etc. (3) Rubber wheels, being bonded with natural or synthetic rubber, are somewhat elastic in nature. (4) Shellac wheels are used for producing high finishes on such items as camshafts and paper mill rolls (5) Silica bonds find application in operations where heat generated in grinding must be kept to a minimum. Silicate-bonded wheels are mild acting and are used in grinding edge tools of all kinds. Rubber, pencil and ink erasers contain abrasive grains and similar soft rubber wheels, sticks and other forms are made for finishing soft metals.

Coated abrasives consist of sized abrasive grains cemented to paper or cloth backing. Sandpaper is coated with crushed quartz on paper because its grains have much sharper cutting edges. Usually emery cloth today is coated with silicon carbide or aluminum oxide. Many different materials mostly natural but some manufactured are used in making soaps, cleaners and polishes. A household cleanser should not contain quartz or any mineral of equal or more hardness. The abrasive should not contain calcium carbonate, calcium sulphate or other easily reactive lime compounds because lime reacts with most soap to form insoluble substances which are very difficult to remove from glass or enamel surfaces [1].

CHAPTER 3

Uses & Specifications

3.1 USES

Many different materials, mostly natural and some manufactured are used as abrasive. Low price is the primary factor in the selection of the abrasive.

Abrasives in one or other form have been used for over two million years. The first crude wooden tools were ground by rubbing them to shape or sharpen against sandstone or flint. There are three basic forms in which abrasives are used, namely loose, granular and powdered particles. These particles are bonded with various agents into wheel, segmental or stick shapes. The particles deposited with glue or synthetic resins on paper or cloth are known as coated abrasives. The major use of quartzite is in sandpapers. It is cheaper than garnet and has maintained a small market on that basis. It is also used as an abrasive in hand soaps, scouring compound, metal polishing, etc. The abrasive uses of silica sand include glass polishing. Abrasive applications for diamonds include their use in rock drilling.

Industrial grade diamond, i.e. diamond that does not meet gem quality standards for colour, clarity, size or shape continued to be used principally as an abrasive in many applications despite its initial cost. Even though it is more expensive than the competing abrasive material, diamond has been proved to be more cost-effective in numerous industrial processes because it cuts faster and lasts longer than any other material. In addition to its utility as an abrasive, diamond has other exceptional properties including chemical, electrical, optical and thermal characteristics that make it the best material available to industry for special cause, heat sinks in electrical circuits, wiredrawing and in many advanced technologies. Synthetic diamond (manufactured) using high pressure and high temperature methods compete with natural industrial diamonds as an abrasive mineral and with silicon carbide (SiC), alumina (Al_2O_3), tungsten carbide (WC) and carbon boron nitride (CBN) as manufactured material. Many marketed synthetic diamonds are 0.6 – 0.8 mm and smaller. A very popular type of synthetic diamonds is called "Synthetic Diamond Abrasive (SDA)". It is used for sawing, drilling or milling, stone, concrete aggregate, refractory materials, masonry and asphalt. In many cases, synthetic diamonds are preferred to natural industrial diamonds because they can be sized and shaped as per the customer demands. In general, large crystals are used for cutting softer materials and smaller crystals are used for tougher material.[5]

Corundum was used extensively in grinding wheels. It is employed mainly as a loose abrasive to grind and polish optical lenses. Due to its hardness, which is next to diamond, it is used mainly in manufacturing abrasive material. Since the production of natural corundum cannot cater to the demand all over the world, synthetic corundum is used widely. The principal use of corundum is in abrasives, such as grinding wheels, papers and cloth, mortar and wiredrawing and grinding powder. Corundum (other than gem variety) is used mainly as an abrasive. For abrasive purposes, it should have a bright glassy luster, the broken grains should be uneven angular and sharp and should have no cleavage or parting planes. Corundum of fine and flour grades is used as loose grains for polishing metals, rocks and gems and for grinding and bevelling glass. Corundum grains are used in the manufacture of grinding wheels, corundum cloth and corundum paper. When pure, corundum is very hard and rough for use in grinding and polishing. Emery is preferred because of its less hardness. Corundum, a naturally occurring anhydrous oxide of aluminium (Al_2O_3) contains as much as 52.9% alumina.

Emery is used mainly for manufacture of grinding wheels. Nowadays, its main use is in the construction of non-skid concrete floors and pavements.

Garnet is used primarily to coat paper and cloth products, for grinding optical lenses and sand blasting. Natural industrial garnet is utilised mainly for abrasive purposes. Almandine and grossularite are the common minerals which are used in the manufacture of abrasives. Garnet is washed, crushed, roasted and then used in the manufacture of coated abrasives. Garnet abrasives are used mainly in wood, rubber and plastic work industry for surfacing and polishing purposes. Finely-ground garnet is used for non-skid floor paint, spark plug cleaning, plate glass grinding, optical lens grinding, etc. Garnet paper and cloth are common abrasive products. Carborundum Universal Ltd., Thiruvottiyur, Chennai, Cut Fast Abrasive Tools (Pvt) Ltd., Chennai and Straw Board Manufacturing Co. Ltd. Shaharanpur, Uttar Pradesh are the major consumers of abrasive garnet to produce coated and bounded abrasives. Tamil Nadu is the main producer of abrasive garnet.

Few firms in India are utilizing felspar as a binding agent in the manufacture of abrasives even though its major application is in ceramic industry.

Bauxite is a mixture of the minerals gibbsite Al_2O_3 $3H_2O$, boehmite $Al_2O_3H_2O$ and diaspore Al_2O_3 H_2O. Bauxite is the chief source of aluminium. Bauxite finds its use the manufacture of aluminium, alumina, refractory bricks, chemicals like alum, abrasives and cement. Abrasive grade bauxite is available both from Gujarat and Maharashtra. Various abrasives are produced by fusion of calcined bauxite in an electric furnace. Abrasive producers consume bauxite having Al_2O_3 48% and above, Fe_2O_3 15 to 20% and SiO_2 5% max. This type of bauxite is available in Tamil Nadu. Some consumers use bauxite containing Al_2O_3 40% and Fe_2O_3 30% available in Gujarat. Consumers also use bauxite containing Al_2O_3 50% and Fe_2O_3 15% available in Jharkhand for the manufacture of abrasive.

Diamonds are also versatile abrasives. Industrial diamonds are used for machining tungsten carbides, glass, ceramics, ferrous and non-ferrous metals of a great variety. Large quantities of diamonds are manufactured synthetically for industrial applications and uses. Synthetic and industrial diamonds make up 90 percent of the world's industrial diamond supply. Synthesised polycrystalline diamond is competitive with natural stones in many applications. However, development is accepted in the synthesis of intermediate and large size industrial stones suitable for all uses now served by natural stones. Industrial diamonds are consumed mostly by manufacturers of drill bits, grinding tools and stone cutting and polishing machines.

Diatomite is used as an abrasive in metal polishing in automobiles. Felspar is used mainly in ceramics and glass industries. Minor quantities of felspar find use in refractory, abrasive and electrode industries. Quartz, quartzite, silica sand and moulding sand are consumed in various domestic industries like glass, ferro-silicon, iron & steel, refractory, foundry, ceramics, cosmetics, electrical, abrasive, paint, etc. In the production of silicon carbide (an abrasive, refractory and metallurgical deoxidant), quartz is used. General specifications of silicon carbide (abrasive) are as follows :

Silicon carbide: SiO_2-99.5% (min), Al_2O_3 – 0.06 to 0.25% (max), Fe_2O_3-0.1% (max), grain size 100 mesh but no phosphorus is allowed.

Perlite is a glassy rock of volcanic origin, chiefly rhyolite, having pearl-like luster. Crude perlite is essentially a metastable amorphous aluminium silicate. It has an unusual characteristic of expanding to about 4 to 20 times its original volume when heated to a temperature of 1400°C. It has low density, low thermal conductivity and high sound absorption. The uses of perlite are in building and construction applications as an ultralightweight aggregate in plasters and concretes, loose fill insulation and as a prime ingredient in insulating board and ceiling tiles. Other uses are as filler aids for water treatment and purification, processing of sugar, chemical and pharamaceuticals.[9]

3.2 SPECIFICATIONS

M/s. V.V. Minerals of Tamil Nadu produces garnet and uses it as an abrasive. Their specification for garnet depends on sieve size. After processing the heavy mineral through

electrostatic separator, the material is passed through grit-making machinery for purity and grading by sieving machinery. The sieving machinery classify the material by size like A, B, C, D and E grades. The specifications are given below[9] :

A grade	12 – 24 mesh
B grade	20 – 40 mesh
C grade	30 – 60 mesh
D grade	50 – 80 mesh
E grade	80 – 120 mesh

Indian Rare Earths Ltd (IREL) supply 'M.K'. grade abrasive garnet to different organisations from their mine in Tamil Nadu as indicated below :

Analysis			Mesh (Tyler screen)	Sieve Analysis	
				Sieve opening in microns	Cumulative retained wt%
Non-magnetic	0.2	- 0.5%	-	-	-
Ilmenite	1.0	- 2.5%	35	425	0.5-4.5
Garnet	97.3	- 98.9%	100	150	82.0-97.0
Purity	97%		150	106	98.5-100

From Orissa mine, the IREL supply almandite-type garnet of 95.2% +300 microns, weight 5%.

The specifications used by different abrasive industries for their products in India as collected from Bureau of Indian Standards, Nagpur, are as follows:[11]

(a) **Specifications for coated abrasives**

It has been observed that under tropical conditions, coated abrasives are prone to attack by micro-organism with consequent reduction in the strength of the backing material as well as in the binding power of the adhesive. For this reason, provision has been made for fungicidal treatment of the adhesive. The need for the practical work test for judging the quality of the coated abrasives is well recognised. The Sectional Committee responsible for the preparation of this standard has decided to carry out investigations to develop a work test and evaluation criteria for the various types of coated abrasives specified in this standard. As an interim measure, until the investigations have been completed, a somewhat empirical test has been prescribed for judging the quality and adhesiveness of the abrasive.

(b) **Specifications for emery cloth, emery paper and flint paper**

Emery used shall be synthetic or natural emery containing not less than 55 percent aluminium oxide (Al_2O_3) and shall not have less than 15 percent or more than 35 percent combined iron oxide by mass. Other properties shall be as follows:

Specific gravity : 3.60 min
Hardness : 8.0 on Mohs' scale

Flint used shall be of high grade, crushed from clean hard quartz, quartzite or flint and free from extraneous material.

(c) Specification for waterproof silicon carbide paper

The abrasive used shall be of good quality fused silicon carbide free from extraneous material and shall have relative density not less than 3.12.

For the use in special and mechanised applications, abrasive used shall be of high grade, free from extraneous materials and shall conform to the following specifications:

Type of abrasive	Minimum sp. gr.	Hardness on Mohs' scale	Quality
Garnet	3.40	7.0	High grade material crushed from hard, fast-cutting commercial garnet.
Emery	3.60	8.0	High grade natural or synthetic emery containing minimum 55% aluminium oxide and not less than 15% or more than 35% aluminium oxide and not less than 15% or more than 35% combined iron oxide by mass.
Aluminium oxide	3.90	9.2	Good quality aluminium oxide
Silicon carbide	3.12	9.5	Good quality fused silicon carbide

(d) Specifications for flour mills

Emery stone shall be manufactured by calcined magnesite powder, magnesium chloride solution and emery grains in suitable proportion, casting them in suitable cast iron moulds at a temperature 27±3°C and at minimum 70 percent relative humidity. The raw material used is calcined magnesite. The chemical composition of calcined magnesite is as follows:

Characteristic	Requirement
1. Magnesium oxide (MgO), percent by mass	85 min
2. Calcium oxide (CaO), percent by mass	2 max
3. Carbon dioxide (CO_2), percent by mass	5 max
4. Total contents of MgO, Al_2O_3, SiO_2 and loss on ignition, percent by mass	99 max

(e) Specifications for diamond or cubic boron nitride abrasive grinding wheels

The general requirements for the true running of grinding wheels, when tested, shall fall within the limits specified as follows:

Shape	Total indicator reading (TIR) mm		
	Periphery	Side	Rim
1. Peripheral grinding wheels	0.05	0.08	-
2. Straight cup and dish	0.08	-	0.05
3. Taper-cup grinding wheels	0.05	-	0.05

All grinding wheels shall be balanced dynamically. All grinding wheels shall have chamfer at the bore. The type of bond for the grinding wheels shall be resin or metal.

As a basic value for diamond concentration in grinding wheels, 100 are equivalent to 4.4 carats per cubic centimeters (0.88 gm/cm^3). This figure corresponds to 25 percent by volume, taking the density of diamond as 3.52 gm/cm^3. Standard concentration shall be 125, 100, 75 and 50. Other concentrations may be as agreed between the manufacturer and the purchaser.

The diamond or cubic boron abrasive grinding wheels have diamond grains of different grit size designation bonded together with metallic, resinoid or similar bonds and held on metal or resin-filled body. These wheels are used for finish grinding of tungsten-carbide-tipped tools, cutters, dies and in ceramics industry for grinding ferrite. These are also used in the manufacture of optical lenses. The selection of grit is shown below:

Surface finish	IS grit designation	
	Diamond	CBN
Very coarse	D 181	B 181
Medium coarse	D 151	B 151
Medium	D 126	B 126
Medium fine	D 107	B 107
Fine	D 91	B 91
Very fine	D 76	B 76
Extra-fine	D 54	B 54
Superfine	D 46	B 46

CBN = Cubic boron nitride

(f) Specifications for abrasive emery grain

The abrasive material shall be natural or synthetic emery or corundum and shall comply with the requirements as follows :

Abrasive material	Specific gravity (min)	Hardness on Mohs' scale (min)	Aluminium oxide content as Al_2O_3 (min)
Emery (natural)	3.8	8	55
Emery (synthetic)	3.6	8	55
Corundum	3.9	9	90

The following is an example of grading emery abrasive grain grit 50:

Take grit 50, all material should pass through the coarsest sieve (in this case, aperture size 425). All material may pass through the next coarsest sieve aperture size 355 but not more than 25% may be retained on it. At least 50% shall be retained on the sieve aperture 212. Not more than 10% shall pass through sieve aperture 150 and collect in the pan. Loss on ignition shall not exceed 2.0%. The abrasive grain shall not contain more than 35% magnetic materials. For marketing the abrasive, each pack shall be marked with the following information:

(a) Manufacturer's identification mark
(b) Grit number
(c) Abrasive material
(d) Year or code and country

Assemble the desired net of sieves used for testing each grit category in order of mesh size with the coarsest sieve on the top, progressing to the finish with a pan at the bottom. Pour the test sample on to the coarsest test sieve, place a cover on the top sieve and set the entire unit in the sieving machine with a receiver.

CHAPTER 4

Indian Occurrences, Prospecting and Reserves of Abrasive Minerals

4.1 NATURAL ABRASIVES

Indian occurrences of different abrasive minerals generally fall under natural abrasives. The use of natural abrasives has declined substantially since the beginning of this century. Manufactured abrasives are more uniform and efficient.

4.2 DIAMOND

Diamond is the hardest substance known. All diamonds are carbon in crystalline form. Generally, diamond is colourless. However, the presence of impurities imparts various colours, such as blue-white, yellow, pink, brown, green, grey or black. Diamonds are manufactured synthetically in large quantities.

4.2.1 Occurrences

Diamonds are mainly found in (1) South India in Andhra Pradesh comprising Anantapur, Cuddapah, Guntur, Krishna, Mahboobnagar and Kurnool districts; 2) Eastern Indian tract of Orissa, mostly lying between Mahanadi and Godavari valleys; (3) Panna district of Madhya Pradesh in Central India; (4) Kimberlite in basal Chhattisgarh Formation and surrounding granite terrain in Saraipalli area of Raipur district; and (5) Chandrapur, Nanded and Gadchiroli districts of Maharashtra.

The Wajrakarur area in Andhra Pradesh (about 14 km south of Guntakal Junction) was once a flourishing mining field. In other areas of this tract, diamonds have been worked in the past from the gravel beds only. However, in Kurnool district, diamondiferous conglomerate and breccia are found lying at the base of the lower most quartzite bed of Banganapalle Stage of Kurnool System. The second tract comprises alluvium of Mahanadi in Sambalpur district, Orissa; in lateritic grits at Wairagarh, Chandrapur district, Maharashtra; and in the sands of Koel river in Palamau district, Jharkhand. The third tract, the Panna mining field in Madhya Pradesh is the most important where diamond mining is still continuing. In this area, diamond is recovered from (1) ultrabasic intrusive rocks forming a pipe or neck at Majhgawan and (2) conglomerate beds.

4.2.2 Prospecting

In Chhattisgarh, assessment of four kimberlite bodies identified in the Indravati basin area in Bastar district was discontinued in January 1998 by Geological Survey of India.

During 1997-98 and 1998-99, regional search for kimberlite in Basal Chhattisgarh Formation and the surrounding granitic terrain in Saraipalli area, Raipur district, was carried out and an ultrabasic dyke identified within the purple shale beds of Lower Chhattisgarh Sediments. Ground evaluation of aerogeophysical anomalies in parts of Raipur district and adjoining districts of Orissa was continued for locating kimberlites. Search for kimberlite and its indicator minerals was continued during1998-99 in Tapti lineament zone in Raigarh and Surguja districts, Chhattisgarh. Sampling was carried out in the area on either side of the upper part of main stream. A multidisciplinary programme of search for kimberlite

was taken up in parts of Chandrapur, Nanded and Gadchiroli districts of Maharashtra and a number of basic and ultrabasic bodies have been identified within the granulitic rocks. During 1997-98 and 1998-99, investigations were undertaken for the search of new kimberlite bodies in the granite-greenstone belts in the Central Segment of Wajrakarur kimberlite field and within the Closepet Granite in Kalyandurg area, Anantapur district. Diamondiferous kimberlite bodies were also located at Anumpalle, Dibbasanipalle, Golapalle and Kalyandurg area in Anantapur district. In Karnataka, search for kimberlite in granitic terrain of Gulbarga and Raichur districts resulted in the discovery of kimberlite pipe near Yagapur in the extension of Maddur Narayanapet kimberlite field for the first time. Besides, aerial prospecting for diamond is also being carried out by a number of multinational companies in Chhattisgarh, Andhra Pradesh and Karnataka.

4.2.3 Exploration & Development Work carried out by Different Agencies

During 1999-2001, in Majhgawan mine of National Mineral Development Corporation Ltd. (NMDC), in Madhya Pradesh, overburden was removed and development has been done in both the directions of the pit and one pipe was being worked. The Directorate of Geology, Government of Orissa, carried out exploration for diamond in Nangalbod area of Nawapada district on 1:50,000 scale over an area of 26.25 sq km and trial excavation for 13.5 cu m in the same area. Detailed exploration was done on 1:2,000 scale over 0.25 sq km in that area. The Directorate also carried out exploration in Dharambandha area of Nawapada district on 1:2,000 scale over an area of 1.65 sq km and trial excavation for 62 cu m to locate source rock of diamond. Mineral Exploration Corporation Ltd. (MECL) has carried out exploration work on Hatupur-II Block, Panna district, Madhya Pradesh. The diamondiferous conglomerates were kept in the custody of NMDC for beneficiation. The treatment plant of NMDC was commissioned.The processing of bulk samples was taken up and the work was in progress. Studies were carried out by NMDC for the occurrences of diamonds in Majhgawan pipe and to ascertain the percentage of gem variety diamond in total production. NMDC also sought for Reconnaissance Permit for diamond exploration in Panna diamond belt of Madhya Pradesh.

4.2.4 Reserves

Table-4.1 : Reserves of Diamond as on 1.4.2000

(Carats)

Status	Grade/State	Proved	Probable	Possible	Total
In situ	All India :Total	609465	600000	1434359	2643824
	Gem	4481	-	521600	526081
	Industrial	984	-	782400	7 83384
	Unclassified	604000	600000	130359	1334359
Recoverable	Total	609465	600000	1434359	2643824
	Gem	4481	-	521600	526081
	Industrial	984	-	782400	783384
	Unclassified	604000	600000	130359	1334359
Statewise recoverable reserves	Andhra Pradesh	5465	-	-	5465
	Chhattisgarh	-	-	1304000	1304000
	Madhya Pradesh	664000	600000	130359	1334359

4.3 BAUXITE

Bauxite is mainly aluminium hydroxide containing varying proportions of iron oxide, silica and generally titania. The aluminium hydroxides present in the bauxite are diaspore and boehmite $Al_2O_3H_2O$ (Al_2O_3-

4.5 DIATOMITE

Diatomite is also known as diatomaceous earth or kieselguhr. It is essentially composed of fossilised siliceous remains of marine microscopic aquatic plants known as diatoms. Pure varieties resemble 'chalk' but more usually they are 'clay-like', being admixed with varying amounts of inorganic impurities, such as clay, sand, calcium carbonate, carbonaceous matter, etc. When pure, rocks are friable, soft, porous and have a low density but dry powders have an apparent density of 7 to 16 lb/cu ft. When impure, they are quite hard[7]. Processed diatomite finds a wide range of applications due to its diatom-like skeletal structure and constitution, low bulk density, soluble impurities, high absorptive capacity for liquids, large surface area, low thermal conductivity, mild abrasive qualities and chemical inertness. Diatomite is used as an abrasive in metal polishing in automobiles.[5]

4.5.1 Occurrences

Workable diatomite deposits of significance have not been established in the country. However, there are few occurrences reported from Gujarat, Rajasthan, Tamil Nadu and Andhra Pradesh. Besides, Camorta and Trinicutta Islands in the Andaman and Nicobar Group of Islands have known occurrences of diatomite about which little information is available.[5]

In India, so far no major deposits of pure diatomite have been found. Some islands in the Nicobar Group contain low grade diatomite and the Mud Banks of the Kerala coast carry abundant remains of diatoms. There are unconfirmed occurrences of a clay-like siliceous earth resembling diatomaceous earth in Rajasthan and near Timmayyapalam in Andhra Pradesh. It is used as a soft abrasive as a filler in filtration and in the manufacture of glazes, enamels and insulation products.[7]

4.5.2 Reserves

Table-4. 4 : All India Reserves of Diatomite as on 1.4.2000

(In '000 tonnes)

Status	Grade/State	Proved	Probable	Possible	Total
In situ	Total/Unclassified	792	-	2251.04	3043.04
Recoverable reserves	Total/Unclassified	633.60	-	1640.30	2273.90
Statewise reserves	Gujarat	-	-	811	811
	Rajasthan	792	0	1440	2232

4.6 EMERY

Emery is an intimate mixture of corundum (Al_2O_3) and magnetite (Fe_3O_4), with or without hematite (Fe_2O_4) and varying in hardness and toughness according to the iron oxide present. Emery is generally reddish-black but may vary from dark-gray to blue-black, depending on the place of origin. At one time, manufactured grinding wheels were made mostly with emery as an abrasive but today, the chief application of emery is in the construction of non-skid concrete floors and pavements. Many users, particularly in small shops and home workshops still refer to grinding wheels as 'emery wheels' although practically all grinding wheels are now made with artificial abrasives of aluminium oxide and silicon carbide.[3]

4.7 GARNET

Garnet is the name given to a group of minerals possessing similar physical properties and crystal forms but dissimilar chemical compositions. Seven species exist, all of which are silicates. Their general formula is $3RO.R_2O_3.3SiO_2$, the bivalent element may be calcium, magnesium, ferrous iron, or

manganese and the trivalent elements are aluminium, ferric iron, or chromium but rarely titanium. Colours vary greatly and include white, pale-green, pale-yellow, deep-green, deep-red and black. Garnet ranges in hardness from 6-8 on Mohs' scale. The industrial use is confined primarily to coated paper and cloth products, grinding of optical lenses and sand blasting [3]. Six minerals have been grouped under the garnet family. These are grossularite Ca_3Al_2 $(SiO_4)_3$, pyrope $Mg_3Al_2(SiO_4)_3$, almadine $Fe_3Al_2(SiO_4)_3$, spessartite $Mn_3Al_2(SiO_4)_3$, andradite, $Ca_3Fe_2(SiO_4)_3$, and uvarovite $Ca_3Cr_2(SiO_4)_3$. They crystallise in the cubic system. A number of occurrences of garnet have been noted in the country but working of this mineral is confined only to Rajasthan, Tamil Nadu, Karnataka and Andhra Pradesh.[8]

4.7.1 Occurrences

More than 99% production in India was reported from Tamil Nadu. A nominal production was reported from Andhra Pradesh and Rajasthan. In Tamil Nadu, garnet was recovered from the beach sands of Tirunelveli and Kanyakumari districts. In Tamil Nadu, deposits have been located in Tiruchirapalli and Thoothukudi districts. In Andhra Pradesh, garnet occurs in Kondalla in Krishna district and Gharbipet and Paloncha in Warangal district. In Rajasthan, Bhilwara district is a very important centre for garnet production. A number of workable bands have been located in this district. In Karnataka, well-formed crystals are found in Hassan, Kolar and Mysore districts. Garnet has been most frequently won from mica pegmatites of Bihar, Rajasthan and Andhra Pradesh. Khondalite rocks in India are the important sources of garnet. Transparent varieties are crimson or deep-red and are prized as gemstones. Such crystals have been picked up occasionally in Jaipur and Tonk districts of Rajasthan.[8]

4.7.2 Prospecting

Semiprecious variety of garnet is reported from Singhbhum district of Bihar around Koderma mica region. Garnet is recovered as a co-product along with other heavy minerals during processing of beach sands in Tamil Nadu which is the single largest source. Garnet is obtained generally from small pits barring a couple of places in Rajasthan where it is recovered from shallow underground mines. The output from mines is graded into two varieties – abrasive and gem depending upon the clarity of crystals.[5]

4.7.3 Reserves

Table- 4.5 : All India In Situ Reserves of Garnet as on 1.4.2000

(Thousand tonnes)

Proved	Probable	Possible	Total
538	27390	26452	54380

4.8 LIMESTONE

Limestone is a calcareous sedimentary rock composed of the mineral calcite ($CaCO_3$), which upon calcination yields lime (CaO) for commercial use. The term limestone includes any calcareous material, such as marble, chalk, tufa, limeshell, coral and marl, each possessing different and distinct physical properties. The crystalline equivalents of limestone having the same chemical composition are calcite and aragonite. In nature, limestone bed is found to occur in varying purity, generally a part of the calcium molecules being replaced by magnesium tending towards magnesium limestone or dolomite limestone. Recrystallised limestone takes good polish and is used as decorative and building stone. It is then called marble.[4]

4.8.1 Occurrences

Limestone deposits are fairly common in India, extensive deposit of limestones are found practically in every State of India. Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Daman & Diu, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nagaland, Orissa, Pondicherry, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal, Madhya Pradesh and Chhattisgarh are the leading producers of limestones in India and the entire production comes from the Vindhyan and Cuddapah Formations in Bastar, Bilaspur, Durg, Morena, Raipur, Rewa and Satna districts.

4.8.2 Prospecting

Geological Survey of India has done exploration work in the Dibang Valley district of Arunachal Pradesh in 1998-99, where geological mapping on 1:50,000 and 1:6,000 scales was done. In this area, samples were taken and reserves were calculated. Rajasthan State Mineral Development Corporation Ltd. (RSMDC) has carried out preliminary geological appraisal in Jaisalmer district of Rajasthan in 1998-99. In 1997-98, Mysore Minerals Ltd. has calculated reserve in Mathodu area, Chitradurga district, Karnataka. In 1997-98, DGM, Government of Assam, has carried out geological mapping on 1:50,000 and 1:2,000 scales and collected samples in Karbi Anglong area, Harihojan district. DGM, Government of Bihar, in 1997-98, has carried out geological mapping on 1:50,000 scale and sampling in the Someshwar hill range in West Champaran. DGM, Government of Andhra Pradesh, drilled boreholes for reserve calculation in the Kamralapuram area, Cuddapah district in 1997-98. In 1997-98, DGM, Government of Maharashtra, carried out geological mapping on 1:25,000 and 1:5,000 scales, collected samples and calculated reserves in the Bori-Andi area of Chandrapur district. DGM, Government of Rajasthan, in 1997-98, carried out geological mapping on 1:50,000, 1:10,000 and 1:2,000 scales, drilling and sampling and calculated reserves. In this process, the districts like Rajsamand, Sirohi, Nagaur, Jaisalmer, Ajmer, Dungarpur, Jhalwar and Sawai Madhopur were covered. In 1997-98, MECL has estimated reserve in the Kurnool district of Andhra Pradesh.

4.8.3 Reserves

Table-4.6 : All India In Situ Reserves of Limestones on 1.4.2000

(Million tonnes)

Proved	Probable	Possible	Total
21861	2940	118677	169941

4.9 QUARTZ, SILICA SAND AND QUARTZITE

The term quartz is often used as a synonym for silica (SiO_2). Silica is the most abundant mineral found in the crust of the earth. It is found in a variety of forms like quartz crystals, quartz sand (silica sand), sandstone, quartzite, tripoli, diatomite, flint, opal, chalcedony, agate, etc. and in numerous other forms depending upon colours, such as purple quartz (amethyst), smoky quartz, yellow quartz, rosy quartz and milky quartz. Glass-sand containing organic and clayey impurities is used in the manufacture of sandpaper, abrasive cloth, etc. Generally, sands crushed from sandstone and quartzite is used. River-borne sands are suitable as they do not possess the angular faces. [4]

4.9.1 Occurrences

The country's resources of quartz, quartzite, silica sand and sandstone are very large and extensive. Many States, namely Andhra Pradesh, Bihar, Delhi, Gujarat, Kerala, Madhya Pradesh, Maharashtra, Karnataka, Orissa, Rajasthan, Tamil Nadu and Uttar Pradesh reported production of glass-sand. In Rajasthan, Jaipur and Sawai Madhopur districts contribute glass-sand. In Gujarat, it is worked in the dry beds of Panam river in Baroda district. In Andhra Pradesh, important and large deposits of quartz are found in Guntur, Khammam, Nellore and Kurnool districts. In Karnataka, large deposits of pure white quartz are found in Belgaum, Mysore, Bijapur and Raichur districts. In West Bengal, a large number of quartz veins are found in Purulia district. In Maharashtra, sandstone is found in Maldi area.

4.9.2 Prospecting

Directorate of Geology & Mining (DGM), Government of Rajasthan, carried out exploration for silica sand in Dausa, Karauli and Jaipur districts and for quartz & felspar in Jaipur and Bhilwara districts during 2000-01. During the same period, Directorate of Mining & Minerals (DMM), Government of West Bengal, carried out geological mapping for quartz in Purulia district.

4.9.3 Reserves

Table-4.7 : In Situ Reserves of Quartz, Silica Sand and Quartzite in India as on 1.4.2000

(Million tonnes)

Mineral/grade	Proved	Probable	Possible	Total
Quartz and silica sand	438	748	1874	3069
Abrasive grade	0.2	0.5	0.2	0.9
Quartzite	237	336	558	1131

4.10 FELSPAR

Felspar is the most abundant rock forming mineral in the earth's crust. Felspar is alumino-silicates with varying amount of potassium, sodium and calcium. The common felspar is potash felspar, namely, orthoclase ($K_2O.\ Al_2O_3.\ 6SiO_2$). Sodium felspar is albite and calcium felspar is anorthite. Pink, brown and grey minerals are common.[5]

4.10.1 Occurrences

India has abundant resources of felspar. Mica pegmatites of Rajasthan, Andhra Pradesh and Bihar are the important sources of felspar. Other States where felspar occurs include, Karnataka, Madhya Pradesh, Maharashtra, Meghalaya, Haryana, Tamil Nadu and West Bengal.[8,5]

4.10.2 Prospecting

DGM, Government of Andhra Pradesh, carried out a study to assess the quality of felspar along with quartz and mica in waste dumps generated over 40 to 50 years around Sydapuram and Pedakalur Mandals of Nellore district. Directorate of Geology & Mining, Government of Rajasthan, in their regional studies for felspar along with other minerals, carried out mapping on 1:50,000 scale over 100 sq km and on 1:10,000 scale covering 5 sq km at Anwa, Rajnagar, Rajkot, Sitapura, Devpura, etc. in Devli tahsil, Tonk district.

DGM, Government of Karnataka, undertook studies for feldspar-bearing pegmatite intrusives in granitic gneiss, hornblende schist, dolerite dyke in parts of Bangarpet tahsil, Kolar district, covering 210 sq km by mapping on 1:50,000 scale.[5]

4.10.3 Reserves

Table-4. 8:In Situ Reserves of Felspar in India as on 1.4.2000

(Thousand tonnes)

Proved	Probable	Possible	Total
17460	22300	38279	78039

4.11 SOAPSTONE

Soapstone is the massive talcose rock of variable talc content (usually 50%), soft and soapy to feel. It is hydrated magnesium silicate 3 MgO_4. SiO_2. H_2O. It is essentially a secondary mineral formed by the hydrothermal actions and regional metamorphism of magnesium-rich rocks like dolomite, pyroxenite, amphibolite, serpentinite, dunite and chlorite. It is the softest mineral known, being 1 in the Mohs' scale of hardness.

4.11.1 Occurrences

Major economic deposits of talc, steatite and soapstone occur in basic igneous rocks, such as peridotite and dunites or with the dolomitic limestones. The best grade talc deposits are found in association with the dolomitic limestones and marble. Magnesite is often found in association with talc. In Rajasthan, steatite deposits are found in the districts of Ajmer, Alwar, Banswara, Dungarpur, Jaipur, Jodhpur, Sawai Madhopur and Udaipur. The largest deposits of superior grade steatite are found only in Jaipur and Bhilwara districts. In Jaipur, the important localities are near Geejgarh, Dausa, Kawa, etc. It is also found in Jharkhand, Andhra Pradesh, Karnataka, Gujarat, Madhya Pradesh, etc. In Andhra Pradesh, soapstone deposits are found in Anantapur, Kurnool, Visakhapatnam and Nellore districts. In Madhya Pradesh, superior quality soapstone is found in Jabalpur and Jhabua districts. In Jabalpur district, important deposits are found at Bhedaghat, Gowari, Lalpur and Rupaund areas. In Jharkhand, the soapstone is found near Chailmo, Kusumarja, Bhowanand, Tirij, Narainpur, Kasitola, Jarsidih and Jangidri. In Gujarat, important occurrences of soapstone are found between Dev Mori and Kundol and at Ghanta, Vartha and Thuravas. In Uttaranchal, extensive deposit of massive soapstone occurs in association with dolomites in Almora district. In Orissa, soapstone deposits are found in the districts of Cuttack, Koraput, Mayurbhanj and Sundargarh. In Cuttack district, large and extensive deposits of soapstone are found between Ballgot and Kuchiranga. In West Bengal, pockets of soapstone are found in Darjeeling district. In Tamil Nadu, inferior quality soapstone occurs in a number of places in Salem district.[7]

4.11.2 Reserves

Table-4.9: In Situ Reserves of Talc/Steatite/Soapstone as on 1.4.2000

(Thousand tonnes)

State	Proved	Probable	Possible	Total
All India : Total	131178	64181	131419	326779
Andhra Pradesh	2230	1880	3334	7445
Bihar	55	35	3	94
Uttaranchal	50010	31441	24989	106441
Gujarat	23	8	8	40
Jharkhand	14	65	323	404
Karnataka	284	620	1349	2255
Kerala	-	-	14390	14390
Madhya Pradesh	1833	3007	6127	10969
Maharashtra	-	2565	14262	16827
Rajasthan	76271	21849	65617	163738
Tamil Nadu	300	2294	348	2943

4.12 APATITE

Apatite is the most abundant crystalline phosphate mineral and is found as an accessory mineral in practically all kinds of igneous rocks. Most of the world's phosphate production is from sedimentary deposits which are accumulation of apatite formed by biological activity. Rock phosphate cannot be strictly called a mineral, because it has no definite chemical composition. It is a secondary deposit formed due to the accumulation of organic remains, like bones and by replacement of limestone, calcite, etc. by phosphoric solutions to form a mixture of calcium phosphate. [4]

Theoretically, percentage composition is as follows:

Chlor - apatite : P_2O_5 41.0, CaO 53.0, Cl 6.0 = 100
Fluor -apatite : P_2O_5 42.0, CaO 55.0, F 3.0 = 100

4.12.1 Occurrences

Apatite occurs mainly in Purulia district of West Bengal, Singhbhum district of Bihar, Visakhapatnam district of Andhra Pradesh and Sikar and Udaipur districts of Rajasthan. Rock phosphate occurs mainly in Udaipur and Banswara districts of Rajasthan, Lalitpur, Tehri Garwal and Dehra Dun districts of Uttaranchal and Jhabua and Chhatarpur districts of Madhya Pradesh. Phosphatic nodules are available in Tamil Nadu and Lakshadweep Group of Islands.

4.12.2 Prospecting

In 1997-98, DGM,Directorate of Geology and Mining Government of Rajasthan, carried out exploration work in Lalmadri, Matkeshwar, Bargula-Goan area of Gura tahsil and Nathdwara near Udaipur. Here DGM carried out mapping on 1:50,000 scale, covering 155 sq.m.

4.12.3 Reserves

Table-4.10 : Reserves of Apatite as on 1.4.2000

(Tonnes)

Status	Grade/State	Proved	Probable	Possible	Total
In Situ	Total	800749	11008469	3025871	14835089
	Chemical and fertilizer	15555	53219	337541	406315
	Soil reclamation & beneficiable	781694	10215250	2498330	13495274
	Others	3500	740000	-	743500
	Not known	-	-	190000	190000
Recoverable	Total	602899	10786469	2720716	14110084
	Chemical and fertilizer	15555	53219	337541	406315
	Soil reclamation & beneficiable	583844	10215250	2193175	12992269
	Others	3500	518000	-	521500
	Not known	-	-	190000	190000
Statewise Recoverable	Andhra Pradesh	15555	23219	337541	376315
	Jharkhand	-	2110000	960000	3070000
	Rajasthan	5684	30000	-	35684
	Tamil Nadu	-	-	190000	190000
	West Bengal	581660	8623250	1233175	10438085

4.13 CALCITE

Calcite is a carbonate of calcium ($CaCO_3$) containing 56% CaO and 44% CO_2. It is one of the important industrial minerals also known by 'Calc spar'.

4.13.1 Occurrence

Calcite occurs in Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Rajasthan, Tamil Nadu and Uttar Pradesh.

4.13.2 Prospecting

DGM, Government of Rajasthan, investigated for calcite in Bhopari, Jhalna, Siriyari villages in Pali district and Sei, Derla, Teja-ka-Vas in tahsil Kotra in Udaipur district but could not found potential deposits.

4.13.3 Reserves

Table-4.11: Reserves of Calcite as on 1.4.2000

(Tonnes)

Status	Grade/State	Proved	Probable	Possible	Total
In Situ	All India : Total	10137335	3320033	4442708	17900076
	Chemical	488771	600049	1980502	3069322
	Glass & ceramic	412221	928954	874422	2215597
	Poor/low	-	85110	121200	206310
	Others	-	43411	22813	66224
	Unclassified	59564	361977	1022000	1443541
	Not known	9176779	1300532	421771	10899082
Recoverable	Total	9140342	2023645.80	2636273.40	13800261.20
	Chemical	346260	512890	1487902	2347052
	Glass & ceramic	168610	256068.80	497552.90	922231.70
	Poor/low	-	70383	66080	136463
	Others	-	34729	13688	48417
	Unclassified	53523	316933	299000	669456
	Not known	8571949	832642	272050.50	9676641.50
Statewise Recoverable	Andhra Pradesh	7766721	97120	117950	7981791
	Gujarat	-	-	6890	6890
	Haryana	24960	24960	24960	74880
	Karnataka	-	35431.80	28722.90	64154.70
	Madhya Pradesh	272913	397586	342302.50	1012801.50
	Rajasthan	1075748	1468548	2029308	4573604
	Tamil Nadu	-	-	79140	79140
	Uttar Pradesh	-	-	7000	7000

4.14 DOLOMITE

Dolomite ($CaCO_3.MgCO_3$) theoretically contains $CaCO_3$ 54.35% and $MgCO_3$ 45.65%. However, in nature, exact proportion of dolomite is not available. Hence, rock containing 40-45 % $MgCO_3$ is generally called dolomite.

4.14.1 Occurrences

Occurrences of dolomite are widespread i India. It occurs mainly in the States, viz. Arunachal Pradesh, Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh and West Bengal. Dolomite also occurs in Bihar and Tamil Nadu in small quantity.

4.14.2 Prospecting

Preliminary appraisal by GSI in dolomite area along Mahola, Alsindhi, Kadar, Chaba-Khaira section of Mandi and Shimla in Himachal Pradesh indicated silica content of dolomite ranging between 0.48 and 2.5%. A number of dolomite samples from Khatpal, Tattpani and Paruali Formations were also found to be suitable for use[5].

Table-4.12 : In Situ Reserves of Dolomite as on 1.4.2000

(Thousand tonnes)

Proved	Probable	Possible	Total
1062451.52	1126422.62	5159758.33	7348632.47

4.15 PERLITE

Perlite is a glassy rock of volcanic origin, chiefly rhyolite, having pearl-like luster. Crude perlite is essentially a metastable amorphous aluminium silicate.

4.15.1 Occurrences

In India, perlite occurs in Rajkot district of Gujarat.

4.15.2 Reserves

Table-4.13 : Recoverable Reserves of Perlite as on 01.04.2000

(Thousand tonnes)

State	Proved	Probable	Possible	Total
All India/Gujarat	361	316	334	1011

CHAPTER 5

Mining Methods

5.1 GARNET

The mining methods adopted for garnet minerals occurring in the beach sand of Kanyakumari in Tamil Nadu by Indian Rare Earths Ltd for their captive mines are as follows:

The beach washings containing heavy minerals (including abrasive mineral) is collected manually from different beaches. The inland sand containing the heavy minerals is being mined by a floating dredger which dredges the sand and pumps to the land based wet concentrator plant located nearby where the sand is concentrated and sent to the mineral separation plant. The beach washing collected from the beaches and the concentrate from the inland deposits are further concentrated in another wet concentrator plant. Further, the concentrate from the wet concentrator plant is dried, separated into individual minerals in the mineral separation plant using the physical properties of the mineral.[9]

M/s. V.V. Mineral, Tirunelveli, Tamil Nadu, produces Garnet used as abrasive. The Garnet ore mined in the lease area will be heaped in the adjacent lands for easy transportation to the factory. It is transported to the factory by lorries and heaped in the factory drying yard. This drying yard contains the garnet ores tansported from other mines also. In the drying yard, the garnet ore will be sundried manually. After sundrying, it is transported to factory through conveyor and pulverizer. At the first point by using one sieve, the shells and other impurities are removed and the ore is then pulverised and heaped inside the factory. Magnetic separators separate the garnet and other heavy minerals as one part. The other part containing waste land is rejected. The waste material is transported back to the beach i.e lease area. The garnet and the heavy minerals are again processed through electrostatic separator which separates the heavy minerals from garnet. The processed garnet is washed with sweet water and dried again, so that the chloride content and the conductivity is reduced to the international standard. The purified garnet is again passed through the grit-making machinery and by adjusting the machinery, particular size of grits is obtained. The final product is transported to weighing point, weighed and packed according to customer's instructions.

Garnet is generally obtained from small pits, barring a couple of places in Rajasthan where it is recovered from shallow underground mines. The output from mines is graded into two varieties, i.e.abrasive and gem, depending upon the clarity of crystals. Clear, flawless and rich coloured crystals of garnet are sold as precious and semiprecious stones after their cutting and polishing in Jaipur and Delhi.

5.2 DIAMOND

Diamonds are also versatile abrasives. In Madhya Pradesh, diamond is mined from Majhgawan area by Nationsl Mineral Development Corportion Ltd.(NMDC). It is fully mechanized mine. It is worked by open-pit in tuff rock. Diamonds are also recovered from Conglomerate and gravel beds at shallow depths. The kimberlite is the mother rock in Majhgawan area. After mining, it is fed to crushing plant and it is processed through Heavy Media Separation System in processing plant for recovery of diamond. India is one of the largest exporters for cut and polished diamonds. The Indian diamond industry depends mainly on the imports of rough diamond. Cut and polished diamonds are then exported. After issue of guidelines for relaxation of maximum area for carrying out aerial prospecting by Government of India,

efforts were made for collaboration with foreign companies for exploitation of diamond deposits to boost the diamond production and to bring the state-of-the-art diamond mining technology into the country.

Indian craftsmen are experts in cutting and polishing diamonds, particularly of small sizes. However, mechanisation and use of modern techniques in cutting and polishing diamonds are being recoursed presently by many companies in India. Industrial diamonds are consumed mostly by manufacturers of drill bits, grinding tools and stone-cutting and polishing machines.

5.3 APATITE/ ROCK PHOSPHATE

Apatite is the most abundant crystalline phosphate mineral and is found as an accessory mineral in practically all kinds of igneous rocks. Apatite mining was confined to Visakhapatnam district, Andhra Pradesh and Purulia district, West Bengal. In one of the apatite mines in Andhra Pradesh, manual mining was carried out by putting inclined shafts, following the dip of the ore body and by lateral development of levels along the strike.

In Beldi mine of West Bengal Mineral Development Corporation (WBMDC), apatite is mined by opencast method with partial mechanization. Holes are drilled by jackhammers and blasted with special gelatine using electric detonators or ordinary detonators and safety fuses. The blasted material is sorted out, sized and graded. Low grade ore is generally unsaleable and stacked separately. Investigations carried out by fertilizer Corporation of India had established the amenability for beneficiation of +20% P_2O_5 material economically. The marketable ore is dispatched to Rangadih near Birbhum railway station, where it is ground to 60 to 100 mesh and supplied for manufacturing NPK mixture and for direct application to the soil. Phosphorite production was reported from 11 mines in public sector and one mine in private sector. Of the 11 mines, two were in Madhya Pradesh at Hirapur in Chhatarpur-Sagar district and Khatamba in Jhabua district, six in Rajasthan at Jhamarkotra, Maton, Kharbaria-ka-Guda, Badgaon and Kanpur in Udaipur district and Sallopat in Banswara district and three in Uttar Pradesh at Maldeota and Durmala in Dehra Dun district and Sonrai in Lalitpur district. The only mine in private sector was in Tehri Garhwal district of Uttaranchal. This mine produces gypsum also. The Khatamba mine in Jhabua district and Hirapur mine in Chhtrapur- Sagar districts of Madhya Pradesh are opencast mines, operated manually by Madhya Pradesh State Mining Corporation. Compressed air Jackhammers are deployed for drilling.

The Jhamarkotra phosphorite mine of Rajasthan State Mines and Minerals Ltd., Maton mine of Hindusthan Zinc Ltd.(HZL), Kanpur, Badgaon, Kharbaria-Ka-Guda and Sallopat mines of Rajasthan State Mineral Development Corporation Ltd. (RSMDC) are opencast and mechanised shovels and dumpers are used for removing ore and overburden. Mining is carried out by underground method at Maldeota mine and at Durmala mine of Pyrites,Phosphates and ChemicalsLtd.(PPCL) in Dehra Dun district, Uttarnchal. For stoping, conventional induced room-and-pillar method at Maldeota and shrinkage method at Durmala are being adopted. Due to depletion of opencast reserves at Maldeota, the production target will be met by underground mining. The Sonari mine in Pisnari-Tori-block, Lalitpur district, Uttar Pradesh is an opencast mine operated by Uttar Pradesh State Mineral Development Corporation Ltd. (UPSMDC).

5.4 CORUNDUM

Corundum is mined from shallow, open pits by manual operations. Desired mesh sizes are obtained by grinding and then marketed as abrasives. In Madhya Pradesh, the industrial grade corundum is sent to the abrasive factory at Hanumana in Rewa district. The output from Bellary district, Karnataka, caters to the abrasive units in Bangalore and production from Tonk district, Rajasthan is dispatched to various abrasives units in Jaipur.

5.5 DIATOMITE

The light-coloured, porous and friable sedimentary rock that is composed of the siliceous shell of diatoms unicellular aquatic plant of microscopic size is called diatomite. It resembles chalk but it is much lighter than chalk and does not effervesce in acid. Under a power microscope, the form of diatoms can be distinguished. Meagre and sporadic production of diatomite was reported occasionally from Pandava and Khadsaliya areas in Bhavnagar district, Gujarat. Almost the entire domestic requirements are, therefore, met through imports. Diatomite is used as an abrasive in metal polishing in automobiles and toothpastes etc. Workable diatomite deposit of significance have not been established in the country. However, there are few reported occurrences from Gujarat, Rajasthan, Tamil Nadu and Andhra Pradesh. Besides, Camorta and Trinicutta in the Andaman and Nicobar Group of Islands have known occurrences of diatomite.

5.6 FELSPAR

Felspar is worked chiefly worked from pegmatites. Mining is carried out generally by manual method. Most of the mines are opencast. Significant output of felspar is generated as an associated mineral during mining of quartz, mica and beryl. The entire production from Tamil Nadu and part from Karnataka is reported to be associated with quartz. Important mining centes are clustered in Ajmer district in Rajasthan and Nellore district in Andhra Pradesh. As felspar occurs in association with other minerals, top soil and over-burden are removed to expose pegmatites. It is then broken either manually or by drilling and blasting. The broken material is sorted out and sized. Sizing is generally done by crushing. Crushed felspar is mechanically separated with suitable screens to obtain product of different mesh sizes as required in the market. Washing is sometimes done to upgrade the product by removing washable quartz, clay,etc. The processed felspar is dispatched to different consignees.[5]

5.7 QUARTZ AND OTHER SILICA MINERALS

Mining for silica minerals, is carried out by opencast method. Quartz produced in the form of lump along with other associated minerals is invariably crushed into pieces and hand-picked before it is dispatched to the consuming industries. Glass sand is screened generally and washed to remove all the deleterious constituents for its use in glass industry. Gujarat Mineral Development Corporation Ltd., one of the leading producers of silica sand in the country, produces silica sand in different mesh sizes by grinding and screening in its plant at Surajdeval, Surendranagar district, Gujarat. Andhra Pradesh Mineral Development Corporation Ltd., has two crushing plants at Mahaboobnagar district, having crushing capacity of 45 tonnes and 1,000 tonnes a month each. Besides, Maharashtra Minerals Ltd, has a 50,000-tonne per year beneficiation plant in Sindhudurg district.

5.8 BAUXITE

Fully-mechanized operations are followed in a few captive bauxite mines of the alumina/aluminium plants. They use compressed-air-powered drills for drilling blastholes, power shovels or excavators for ore/overburden handling and trucks and dumpers for transporting the ore and overburden. Separate benches are maintained for the overburden and ore body. The height of benches in ore varies from 1.5 to 7.5 m. The depth of working extends upto 15 m. In a number of mines, operations are semi-mechanised, but handling of ore is manual. Mechinary is generally deployed in overburden.

Whenever bauxite occurs as small lenses or pockets or as segregations in murrum and laterites, it is difficult to mechanise the mining operations. Many bauxite mines are small and are worked manually.

Aluminium oxide abrasive is derived from bauxite ore which is mainly aluminium hydroxide. The ore is calcined to drive off excess water and then exposed to high temperatures in an arc-type electric furnace. The chips and coke are added to the dried calcined ore to remove impurities. The refined aluminum oxide comes out of the furnace in a large lump called pig. It is crushed and rolled into small grains, treated magnetically to remove ferrous impurities and washed. Varieties of abrasives having different degrees of toughness and friability are produced by modifications of the refining processes or additions of various minor substances.[10]

5.9 PERLITE

Perlite is a glassy rock of volcanic origin, chiefly rhyolite, having a pearl-like luster. Crude perlite is essentially a metastable amorphous aluminium silicate. It expands to about 4 to 20 times its original volume when heated to a temperature of 1400°C. It has low density, low thermal conductivity and high sound absorption. There was only one reporting opencast mine located in Rajkot district of Gujarat and operated in the private sector.

5.10 CALCITE

All calcite mines in the country are worked manually by simple opencast methods confined to shallow depths except the mechanized Belka-Pahar mine in Sirohi district, Rajasthan. There are certain difficulties in the mining of transparent crystals because transparency is damaged by pressure, resulting in internal imperfections and cracks. Calcite is marketed usually after pulverizing or some initial processing and grinding in fine powder of 200 to 300 mesh. In Rajasthan, Wolkem (Pvt.) Ltd., the principal mining company markets its products under three different trade names: Calstar snow-white powder with 100% whiteness, Calcium white powder with 98.4% whiteness and Belsum white powder with 95% whiteness.

5.11 LIMESTONE

In India, Limestone mines are generally worked opencast. Big mines are mechanized and captive to cement and iron & steel industries. Some mines have well laid road-cum-rail routes and aerial ropeways. . Coral limestone is mined in Ramanathpuram district, Tamil Nadu, from soft reefs manually using heavy iron crowbars.

5.12 DOLOMITE

Dolomite mines are generally worked opencast. Manual working is in vogue in most mines. However, a few mines are semi-mechanised.

CHAPTER 6

Abrasive Industry in India and Production Technology

6.1 ABRASIVE INDUSTRY IN INDIA

In India, there are a number of units producing various abrasives. India's abrasive industry is a duopoly with Carborundum Universal Ltd. (CUL) and Grindwell Norton Ltd (GNL) controlling 83% of the market. Manufacturers and end-users have to develop products fitting the required specifications. Abrasives can be classified as coated and bonded abrasives. Bonded products constituted 66% market and coated products 24%. Demand for abrasive products is linked to overall growth in industrial sector. The main user sectors for abrasive products (automobile, steel, bearings, construction and fabrication) are passing through a recessional phase. Hence, the Indian abrasive sector is witnessing a slowdown. Valuations will remain subdued until a recovery begins. Manufacturers and end-users have to develop products fitting the required specifications after repeated trial runs. High-performance specifications are required. This implies that a large sections of these products (60%) have to be customized.

Technology for development of special grains used in abrasive products has enabled Carborundum Universal Ltd. and Grindwell Norton Ltd to maintain a combined share in excess of 80% over the last forty years. In general, raw material cost is 20-22% of sales (the main raw materials are abrasive grains, such as silicon carbide, aluminium oxide, zircon, solgel) while power accounts for 8% of sales. Manufacture of abrasive grains is a power-intensive process. Grindwell Norton Ltd produces 70% abrasive grains which is silicon carbide and aluminium oxide and imports the balance (zircon, solgel) requirement. However, unlike Carborundum Universal Ltd. which generates power in-house, Grindwell Norton Ltd. has to purchase power from outside which places it at a relative disadvantage, i.e. power cost is 8% of sales against 6.5% for Carborundum Universal Ltd. In India, bonded products account for 66% and coated products 33% market. The coated products are used more for finishing applications. In India, products finishing is on increase and, therefore, the coated segment is expected to grow at a faster pace than the bonded segment. Demand for abrasive product is linked to overall growth in the industrial sector.

The abrasive industry records a growth rate 2-3% higher than the overall industrial growth rate because abrasive products are consumables which are directly used in metal removal/finishing and user industries. Abrasive products are customerwise in nature and, therefore, domestic producers dominate completely the market with little threat from imports.

The major consumer industries for abrasive and the percentage of total demand from them are as follows:

User industry	Percentage of total demand
Auto ancillaries	35%
General engineering (capital goods)	15 %
Construction and fabrication	12-13 %
Steel	7-8%
Bearing	8%
Others	22%

It is evident from the above table that the automobile sector is the biggest end-user of abrasives followed by the capital goods and construction & fabrication sectors.

It is mentioned that the performance is linked closely to the industrial sector. So the performance will improve only after clear signs of economic recovery emerge. However, because of the duopolistic nature of the industry and the fact the leading companies have taken steps to improve their operational performances, it is believed that the long-term outlook for this industry is positive.

Important producers of coated and bonded abrasives in India are given[18] below :

Coated abrasives

1. Grindwell Norton Ltd., Raigarh, Maharashtra
2. Flexoplast Abrsive (India) Ltd., Aurangabad, Maharashtra
3. Associated Abrasives Ltd., Nasik, Maharashtra
4. Carborundum Universal Ltd., Chennai, Tamil Nadu
5. Cutfast Abrasives Tools Pvt. Ltd., Chennai, Tamil Nadu
6. John Oakey and Moan Ltd., Gaziabad, Uttar Pradesh
7. K.L. Thirani & Co. Ltd., Kolkata.

Bonded abrasives (grinding wheels)

1. Grindwell Norton Ltd, Mora, Uran, Raigarh, Maharashtra
2. Associated Abrasives Ltd, Nasik, Maharashtra
3. Carborundum Universal Ltd, Chennai, Tamil Nadu
4. Cutfast Abrasives Tools Pvt. Ltd., Chennai, Tamil Nadu
5. Industrial Abrasives Co-operative Society Ltd., Mumbai
6. K. L. Thirani & Co. Ltd, Kolkata

Silicon carbide

Major producers of silicon carbide are Grindwell Norton Ltd., Renigunta, Andhra Pradesh having a capacity of 8,000 tpy, Indian Metals & Carbide Ltd., Therubali, Orissa and Carborundum Universal Ltd., Tiruvottiyur, Chengalput, Tamil Nadu.

Systematic data on production of various abrasive products, yearwise/companywise, are not available. Production of silicon carbide by Grindwell Norton Ltd & M/s Indian Abrasives during 1999-2000 and 2000-01 was 3,669 tonnes and 3,922 tonnes, respectively.

The various companies stated above are using minerals like felspar, quartz, bauxite, garnet, etc., sometimes directly or converting the raw mineral into processed form. Finished products obtained by various companies are emery, aluminium oxide, silicon carbide, lapping abrasive, super-garnet abrasive, grinding wheels, etc.

6.2 PRODUCTION TECHNOLOGY

Broadly, abrasive products are classified into two groups, namely:

1. Coated abrasives and
2. Bonded or moulded abrasives

6.2.1 Coated Abrasives

These abrasive products consist of a flexible backing material on to which a layer of an abrasive grits has been fastened by means of an adhesive. Several types of abrasives in a wide range of grit sizes are used and these are combined with a number of backing materials and many types of adhesives. In the form of sheets, belts, disc and rolls, these products are used both by hand and on machines in a very wide range of domestic and industrial processes. The various types of materials used are discussed below.[15]

6.2.1.1 Backing Materials

These include paper, cloth, vulcanized fibre and laminated combination of them. These are used in a range of thicknesses or weights. 'Craft' paper is used for some products. Most of the backing papers are specially made from special papers which incorporate additives like rubber or resin to give the required properties of strength, flexibility and water resistance.

High paper strength is important in many types of coated abrasives. Raw materials having high fibre strength like jute and old ropes are frequently used. Thickness of the paper is specified in terms of the weight per ream of 480 sheets, each 24 x 36". Typical backing papers are 40-, 70- and 130- pound weights. For a given weight, the multiple cylinder paper has a considerable higher strength than that of the single ply paper. Therefore, it is generally preferred for use in belts, etc., where lengthwise strength is important.

With regards to cloth, almost all backing cloths consist of cotton drills or jeans. Jeans are more flexible while drills are heavier and stronger. These are specially woven for coated abrasive manufacture and are very carefully finished, keeping their properties unchanged. Cotton backings are used for coated abrasive manufacture where a flexible material of high tensile strength is required.

Vulcanized fiber is a tough strong material which is used mostly as the backing for the abrasive discs intended for portable sanding equipment. Thickness ranges between 0.015 and 0.030 inch.

6.2.1.2 Abrasive Material

These include flint, garnet, emery, glass, crocus, alumina and silicon carbide. Flint is used to make 'sandpaper' which is employed in the manufacture of leather and felt goods and other general purpose work.

Garnet coated paper is used widely in the woodwork trade and in the furniture manufacturing industry.

Emery cloth and paper are used in the cleaning and polishing of metals. Broken glass is used for 'glasspaper' manufacture, the product being used along with sandpaper as a general purpose coated abrasive, particularly for woodwork and paint work preparation.

Crocus is the basis for a range of papers and cloths used for polishing and cleaning where a comparatively soft abrasive is needed.

Fused alumina is used for heavy grinding operation and on material of high tensile strength. These materials include carbon and alloy steel, tougher non-ferrous metals and also some hard woods. Heavy-duty industrial belts, consisting of fused alumina grains coated on a woven cotton backing, are used widely in grinding and polishing small castings and forgings. Alumina coated fiber discs are used for

floor sanding and similar operations. The types of fused alumina used vary from regular, used on industrial belts, to friable white material that is gaining popularity for woodworking.

Silicon carbide is used exclusively where its great hardness and sharpness are required to give a rapid and clean cutting action. Applications include grinding, smoothing and polishing of glass, plastic, fibrous woods, leather and enamel. The important application is the rubbing down of paint work in the manufacture of motor car bodies.

6.2.1.3. Adhesives

Three general types of adhesives used are animal glue, modified vegetable oil and natural resins. Synthetic resins include phenolic and urea types. Each of these types requires a different process of manufacture in order to coat and dry the adhesives correctly. Heavy-duty industrial belts are invariably made from synthetic resin adhesives.

6.2.1.4 Coating Process

In this process, a large roll of the backfilling material is unwound, generally called the 'web', and then passes through printing a set of coating rollers which transfer adhesive from a tank on to face of the web. Rubber rollers squeeze off excess adhesive. A thin and uniform adhesive film remains on the web. The face of the web to be coated may have been specially treated previously to control the depth of adhesive penetration; deeper penetration of adhesive may lead to brittle product. The first adhesive coating is referred to as the 'maker coat'. After this operation, the sticky web passes through the adhesive grain coating area. This has been carried out by two methods – gravity coating and electrostatic coating.

In gravity coatings, the sticky side of the web is upward and grains fall on to this from a chute while in electrostatic process, the web is reversed and grains are projected upwards by means of electrostatic fields so as to stick to the web which is passed between two high voltage electrodes. The abrasive grains are fed into the projection zone on a continuous belt sliding on the lower electrode which has a voltage in the range of 15 to 50 kV. The grains are charged in the electric field and are projected upwards to stick to the wet web which is sliding on the upper earthed electrode. If the projected grains are splintery or elongated, these will orientate themselves so that their longer axes are normal to the surface of the web. Such an orientation gives a sharper product having higher cutting rate than the randomly oriented gravity-coated material. This technique is especially applicable to medium and fine grain products. In both the processes, excess grains are allowed to fall off and the product is fed in the form of loops through a drying chamber. After drying, the web passes through rollers, which add a second adhesive layer to the abrasive-coated surface. This layer known as 'sizer coat', seals the earlier coat of adhesive and anchors the grains firmly in place. The web is again carried in festoons through a drying chamber in which temperature and humidity are controlled closely for optimum drying and curing the product. After this step, the coated product is wound on to rolls and stored for sale.

In both the processes, the grain density can be controlled. If the web is densely coated, this is termed 'close coat', and if a lower density is used, it is termed 'open coat'. Generally, close coats are used; however, open coats are useful where the products, being ground, tend to clog the surface of the coated material and so destroy the abrasive action. The open-coated material is less liable to clog than the regular product.

6.2.2 Bonded Abrasive

Abrasive material, whether produced synthetically or found in nature, is crushed to particles of desired size. Such particles are called 'grains' or 'grits'. For some applications, the crushing is continued

until the abrasive becomes a fine powder, often called a flour. The flour must be segregated by a flotation method in a liquid. These abrasive loose grains or flours may be used as in lapping, polishing, and buffing. For grinding, hovering and superfinishing, the abrasive grains are bonded together into shapes called grinding wheels, sticks and stones. Abrasive grains when held suitably and moved across a work piece surface remove material by a cutting action.

Grinding wheels, segments and stones are made by sticking abrasive grains together in a controlled manner by means of bonding materials. Many bonding materials have been used as bonds but nowadays generally vitrified, resinoid, silicate, rubber and shellac bonds are used. Of these, the vitrified and resinoid bonds are by far the most important. The basic manufacturing process involves mixing the grain and bond together, forming it the required shape and then baking or firing it to render it permanent. While in use, abrasive grains do the cutting but the bond holds them in position. Each grain is held in a three dimensional network of bond. Bonded abrasivewares are porous because bond does not fill all the spaces in between the grains. Strength of the grains depends upon the type of bond and ratio of bond volume to porosity. This factor is known as 'grade' which controls the way in which grinding wheels work while in use. The grains in the grinding wheels cut like teeth when the wheel is revolved at high speed and is brought to bear against a work piece. Each abrasive tool must have definite physico-mechanical properties which may vary for different jobs. The properties include type, size and shape of the grain; the type and quantity of the bond; the packing of strength; the strength of bonding; and the porosity of the fired product and grinding aids in the form of reactive fillers.

6.2.2.1 Manufacture of Bonded Abrasiveware

The principal bonds are vitrified, resinoid, silicate, rubber and shellac bonds. These are described briefly in the following paragraphs:

(i) Vitrified Bond : It is a clay bond melted to a glass-like consistency or ceramic material formed from very fine-blended clays and fluxes during high temperature firing process. It can be made strong and porous for heavy grinding and is not affected by water, oils, acids or other than extreme temperatures.

In order to make a required mix, the proportions of grain, bond, a temporary binder (such as dextrin) and water are accurately weighed out and thoroughly mixed. In this process, each grain is coated with a layer of bond mixture and when the desired quality is achieved, the mix is ready for forming. Forming is done by placing a required quantity of mix into a mould of the required shape and known dimensions and pressing, vibrating, or tamping it until the mould closes. Moulding can be carried out manually in hydraulic presses, or in automatic presses, but in both the processes, it is necessary to ensure homogeneity of the product. The temporary binder in the wares make it strong enough for handling. The molded item is removed carefully from the mould after dried in oven. Dried mould has to be dressed to size and shape, if necessary, and then it will be ready for firing. The firing process is done carefully by putting the ware on refractory trays. These trays are loaded on to the cars of tunnel kiln and then fired in the controlled cycle of heating, soaking and cooling. During firing, the temporary binder burns out but the body retains its shape because the lightly sintered bond softens as the temperature rises to form a viscous liquid phase. During cooling, it has to be ensured that the ware is not shocked thermally by a too rapid cooling rate, especially in the range covering the transition temperature of the glass bond. This means firing cycle is necessarily long and for large wheels, firing may take ten days. The peak firing temperature ranges between 1100 and 1300°C. Special care has to be taken while preparing silicon carbide wheels to avoid the grains oxidizing during firing. After cooling, ware becomes strong and hard and after cleaning, it is ready for finishing and testing.

(ii) Resinoid Bond : The main constituent of this type of bond is synthetic resins, usually phenol-formaldehyde-type. This can be used as both in liquid and powder form. Mechanically, abrasive grains/powder, resin and fillers are mixed thoroughly. In this mixture, a liquid resin is mixed to form a homogeneous mix. It is necessary that this mix should be free from any agglomerate before going for moulding process. The process of moulding is similar to that of vitrified bond. Moulding to a predetermined density is adopted generally but for thin wheels, it is more satisfactory to press to a standard pressure. The moulded ware is baked in an oven through a controlled temperature cycle which rises to 150 to 200°C. The curing cycle, during which the resin polymerizes to form a hard and strong bond, may last from several hours to 2 or 3 days. Special ovens are needed to ensure uniform temperature distribution. When low porosity bodies of maximum strength are required, the mix is heated in the mould whilst the pressure is being applied. To avoid the breaking of grinding wheel, while in use, several types of reinforcing techniques are used to increase the strength of resinoid wheels. Therefore, large snagging wheels have steel reinforced rings embedded in them during moulding and wire meshes and textile fabrics are also incorporated in wheels.

(iii) Rubber Bond : This is prepared mostly by using natural and synthetic rubber on large heated steel rolls until a plastic mass is produced. Plasticizers, fillers and vulcanizing agent along with a fixed quantity of abrasive grains are mixed into the rubber. This homogeneous mix is fed on to the moving rolls with a definite gap; mix is rolled out into a sheet-like structure from which wheel blanks are stamped. Such blanks are placed on iron plates for baking in an oven at 150 to 175°C temperature till the rubber is vulcanized. Laminating preforms and then hot-pressing them in a suitable mould make thick wheels.

(iv) Shellac Bond : This bond consists of abrasive grains and flake or powdered shellac. This mixture is melted till the shellac melts and forms a uniform coating on the grains. After cooling, this converts into a hard mass which is crushed and sieved into aggregates, each consisting of several grains adhering together. The weighed quantity of these aggregates is distributed evenly in a mould, and then hot-pressed to the required density. After this, wheels are baked in an oven at about 170°C until the shellac has fully cured. This process took about a week. These wheels may not sustain harsh action.

(v) Silicate Bond : This bond is formed from sodium silicate. The abrasive product is made from a mixture of abrasive grain, fillers and a grade of sodium silicate with a high solid content of about 50%. Additives are mixed to improve the grinding property of the product. This mix is also moulded in the similar manner described in the resinoid bond. It is a low strength bond; hence, steel rings reinforcement may be incorporated in the thicker wheels. These wheels are dried and then cured by baking at about 200°C for 20-30 hours.

This bond is weak as compared to resinoid bond and hence has a gentle grinding action which is used for polishing the cutlery, etc. Special resinous and rubber bonds have replaced largely this bond. Nowadays, these bonds are used rarely as compared to other bonds.

6.2.2.2 Grade of Grinding Wheels

The grade of grinding wheel is one of the most important and probably the most difficult factor to check. It is a measure of how strongly the grains are held by the bond. The bonding material in a wheel surrounds the individual grains and links them together by connectors called 'posts'. The sizes and strength of the posts depend upon the kind and amount of binding material in a wheel. The ability to hold its abrasive grains is called the hardness of a grinding wheel. A hard wheel holds its grains more

tenaciously than a soft wheel. A wheel that is too hard for a job keeps its grains after they have become dull. A wheel that is too soft loses grains before they have done full duty. Hardness of the wheel should not be confused with hardness of the abrasive grains themselves.

The structure or spacing of the grinding wheel refers to the relationship of abrasive grains with bonding materials and of those two elements with the voids between them. The spaces in grinding wheel provide room for chips to escape during a cut and for cutting fluid to be carried into a cut[12]. An open structure is desirable for deep roughing cuts in soft materials. It allows the grains to cut at the greatest possible depths and provides space for chips. Ample space for chips is especially needed when the contact between the grains and the work piece surface is relatively long. Dense structure is preferred for harder materials because more grains will be in contact with the work piece, cutting simultaneously. Such structure also helps producing smooth surfaces and assisting the grinding wheel in maintaining its shape. This requires maintaining higher dimensional accuracies. Dense structure grinding wheels can withstand higher pressures.

The grade of abrasive tools is characterized and defined by USSR (erstwhile) Standard GOST 3751-47 which establishes the following scale :

Wheel grade		**Grade designation**
M	– Soft	M1, M2, M3
CM	– Medium soft	CM1, CM2
C	– Medium	C1, C2
CT	– Medium hard	CT1, CT2, CT3
T	– Hard	T1, T2
BT	– Very hard	BT1, BT2
ЧТ	– Extremely hard	ЧТ 1, ЧТ 2

Of the grades M1, M2 and M3, M1 is the softest and M3 is the hardest. The same applies to other subdivisions also.

A standard method of wheel making has been adopted by the abrasive industry and is specified by the British Standards Institution (B.S. 1814 – 1952). This consists of a combination of seven groups of letters and numbers which describe the bonded abrasive material. The size and shape of the grinding wheel or segment are specified separately. Each letter of number in a certain position in the sequence designates a particular property. Almost all grinding wheel manufacturers use substantially the same standard wheel-making system. However, properties of wheels are determined to a large extent by the ways the wheels are made. The processes vary from one plant to another and wheels carrying the same symbols but made by different manufacturers are not necessarily identical.

6.2.2.3 Shapes of Abrasive Tools

Flaring wheels are used in tool sharpening and for surface grinding. The active surface is the face of the various shapes and construction of abrasive tools available. USSR Standard GOST 2424-60 covers as much as 22 shapes of wheels in the size range of diameter 3 to 1100 mm, width 0.5 to 200 mm and bore 1 to 305 mm. The Grinding Wheel Institute has standardized some mounted wheel shapes.

The nine grinding wheel shapes recognized as standard include straight cylinders, with or without recesses in their sides and others described as tapered two sides, straight cup, flaring cup, dish, and saucer. Other shapes may be obtained as specials.[13]

Broadly, grinding wheels are divided into four categories, namely straight, flaring, cylinder and mounted point.

The principal dimensions that designate the size of a grinding wheel are the outside diameter, width and hole diameter. Standard wheel shapes are made in certain sizes only but the variety is large.

Straight wheels are used for cylindrical internal and centreless grinding for surface grinding with the periphery of the wheel and for tool sharpening.

Straight cup wheels are used in sharpening cutting tools and also for surface grinding with the face of the wheel. These wheels can be mounted reliably with flanges or a wheel sieve on the grinder spindle.

Grinding wheels tapered on two sides are used for grinding gear teeth and threads.

Wheels recessed on one and both sides have to accommodate the wheel flanges. This allows the wheel to be advanced closer to the work and facing operations can be combined with cylindrical grinding in many jobs. These wheels are used as the regulating wheels in centreless grinding wheel which can be readily dressed owing to its small area. The conical shape of the cup allows the tool, being sharpened, to advance to the face of the wheel.

Dish wheels have two conical surfaces on one side. This facilitates truing and dressing of the conical surface which is used for grinding the helical surfaces in sharpening certain tools.

Diamond Wheels : In contrast to wheels of other abrasive material, diamond wheels are not solid throughout but consist of a diamond layer (0.5 to 3-mm thick) secured on a body of duralumin, steel or plastic. The concentration of diamond grains per unit volume of the layer may be 50, 100 or 150 percent (a content of 0.878 mg diamond powder per cubic millimeter layer is taken conventionally as a concentration of 100%). Vitrified, resinoid and metal, generally bronze bonds are employed. Grain size of the diamond varies from one micron to 630 microns. Synthetic diamond wheels are available in three grades for making vitrified bonds, for lapping pastes and for metal-bonded tools operating at high specific loads. Depending on the grain size, synthetic diamonds are divided into two groups, namely, grinding powders (with grain size range from 630 to 40 microns) and micron powder with grain size range 40 microns and below.

Diamond grains have sharper angles between their faces, enabling surfaces to be ground with higher class of finish as compared with other abrasive material. Apart from straight wheel & shape, other shapes of diamond wheels are cup, dish, etc.

Diamond wheels are used extensively in sharpening carbide-tipped tools and also for grinding various parts made of cemented carbides.

Grinding Points : There are about seven shapes of grinding points which are commonly used. These are employed for internal grinding and to clean up hard to reach spots in making moulds and dies when grinding wheels are unsuitable. These points do not have through holes and are cemented onto a special stem. Grinding points range from 3 to 40 mm in diameter[13].

Grinding Segments : Grinding segments are used as nine different cross-sectional shapes. The length of these segments varies from 125 to 300 mm. Segmental wheels are used in surface grinding. Such a wheel consists of several abrasive segments clamped in a chuck. The main advantage of segmental wheel is that a damaged segment can be replaced readily without discarding the whole wheel. The spaces

between the segments facilitate the delivery of cutting fluid to the grinding zone and the disposal of chips and wornout particles of the wheel. Owing to the smaller area of contact with the wheel, the work piece is heated less in grinding with a segmental wheel.

6.2.2.4 Abrasive Sticks

Abrasive sticks, often called polishing sticks, stones or hones are manufactured in a multitude of shapes and sizes as well as abrasive materials and abrasive grain size and hardness. Abrasive sticks vary in length from 4 to 6 inches. Like other abrasive material, these sticks are also of two types, i.e. natural and manufactured abrasives.[14]

Abrasive sticks made up of natural material are referred generally as Arkansas stones. They are cut from deposits of novaculite (a hard, dense, silicious rock) found in the Ozark Mountains of Arkansas. These stones are divided into hard and soft, depending upon their density. Hard stones are very fine grit and therefore used for sharpening delicate tools or for fine polishing. Soft stones are not as fine as hard stones and therefore used when a keen, smooth edge is necessary without the super-finish given by the hard stone.[14]

Manufactured abrasives are actually harder than anything in nature except diamond. The two manufactured abrasives are aluminium oxide and silicon carbide. These abrasives are having sharpeness, shape, and smoothness. It is useful for stoning steel-cutting edges where the sharpness of the edge is of greatest concern.

Abrasive sticks made up of vitrified silicon carbide are as hard as diamond. These sticks are extremely sharp and fast-cutting to remove metal more rapidly. Such types of sticks are recommended for operations when the speed of cutting is more important than the fineness of edge.[13][14]

6.2.2.5 Lapping

It is an abrasive process for producing surfaces which are smoother and more accurate than those produced by grinding. Not more than about 0.0001 inch material should be removed in finish-lapping. Lapping is applied usually to steel and harder material. The lap is a rigid plate with an accurate flat surface. Straight narrow grooves in the surface, evenly spaced and running in two directions 90° apart, serve to collect loose abrasive, chips and any dirt. A lap is normally made of a material that is softer than the work piece material. Sprinkling abrasive powder over the surface of the lap and rolling this abrasive into the lap with and held in the lap surface may charge it. Excess abrasive powder used will increase the wear of the lap without doing additional lapping of the work piece. Hence, any loose abrasive particles should be removed from the lap surface.

Lapping is accomplished with abrasive grains which range in size from 120 to 1200 mesh, or even finer depending upon the surface smoothness desired. Lapping may be carried out successfully by hand or by machine depending upon the quality of work piece to be lapped. When flat surfaces are lapped by hand, a lap made of soft, close-grained cast iron is usually used.[16]

The pressure used in lapping must not be too great. It should be distributed evenly to entire surface of a lap to help the lap wear evenly and remain accurate for a longer period. A set of three laps, all charged with abrasive grains of the same size, can be maintained in an extremely accurate flat condition. At regular intervals, the three laps, using all the three possible combinations for using two of the three laps together, are rubbed together carefully for a short time. A lap must be recharged periodically with abrasive without changing the grain size of the abrasive.

Laps are sometimes made as bonded abrasive particle shapes for lapping internal as well as external cylindrical surfaces. Laps may be made of soft steel, copper or brass and also should be adjustable so they can be adjusted to fit continually the cylindrical work piece surface closely. The abrasive may be applied as a lapping compound which consists of abrasive particles in a grease-like carrier. Relative to the work piece, the lap is rotated and given a random axial movement.

Machines like vertical lapping machines, can carry out mechanical lapping.

6.2.2.6 Honing

This is an abrasive process for producing surfaces which are more accurate and smooth than those usually obtained by grinding. This is accomplished with the use of abrasive stones. These are made up of abrasive grains bonded together, similar to grinding wheels. Grain size ranges from 80 to 600 mesh. Size of the grains depends upon the desired smoothness of the surface. The abrasive stones are pressed against and rubbed over the work piece surface, following a non-repeating path. A random cross-marked surface finish, desirable for lubrication, is obtained. Honing is most commonly applied to internal cylindrical surfaces. The honing tools should float in the work piece hole and thus it will follow the axis of the previously produced hole. Cylindrical honing will achieve the following[16]:

(i) an accurate cylindrical surface
(ii) an accurate diameter
(iii) a smooth surface

Depending upon the material being honed, cutting speeds may vary from 50 to 200 surface feet per minute while honing pressure ranges between 150 and 450 psi. Honing may be used for removing material up to 0.020 inch material. Both soft as well as hard material can be honed. Honing can be carried out manually as well as by power. Hand-honed, bonded abrasive stones are used for smoothing the cutting tools. For tungsten carbide and ceramic-tipped cutting tools, hones with an abrasive segment containing diamond or boron carbide grits are used. A very high standard of accuracy is possible by using this technique. Almost any type of bore can be honed. The bores include connecting rods and cylinder for car engines, hydraulic cylinders and steel tubes up to 16 feet long. Vitrified bonded stones containing fused alumina abrasive are used generally for steel components, but metal-bonded diamond hones are now being used on a variety of components of both steel and cast iron.

6.2.2.7 Super-finishing

It is a trade name for an abrasive process which is somewhat similar to honing. It can be applied to internal areas and external cylindrical or flat surfaces. Super-finishing should remove not more than 0.0002 inch material and it is used to produce exceptionally smooth surfaces. The smoothest surfaces are obtained with an abrasive grain size of about 600 mesh. The width of the abrasive stone ranges between 60 and 75% of the hole diameter, hence providing relatively large area of contact. The pressure of the abrasive stone against the work piece surface may range between 10 and 40 psi.

Flat surfaces are super-finished with a cup-shaped abrasive wheel. Super-finishing using abrasive stones held in a carrier is sometimes used to generate flatness and surface-finish in a manner similar to lapping. This operation is sometimes called lapping but as loose stones are used, it is called a honing process.[16]

6.2.2.8 Polishing & Buffing

This process is used for making surfaces smoother. Surfaces which have been polished or buffed may have a glossy finish. Polishing & buffing wheels are usually made of cloth, felt, or similar material so that they will be soft and have a cushioning effect. In buffing, fine abrasive grains in a suitable carrying medium, similar to grease, are applied at suitable intervals to cloth or felt wheels or belts. Buffing removes almost negligible material. In this process, no attempt is made to maintain dimensional accuracy.

CHAPTER 7

Environment (Mining and Processing)

The naturally available placer minerals are simply scooped by using agricultural implements, such as spades and baskets. Hence, the process does not create any environmental problems.

Garnet mining done by M/s. V.V. Minerals, Tamil Nadu, indicates that garnet is environmentally friendly as no chemical treatment or pulverization or grinding, etc. takes place.

Industrial grade diamond, i.e. diamond that does not meet gem standards of colour, clarity, size or shape, continued to be used principally as an abrasive in many applications despite its initial cost. A very popular type of synthetic diamond is called "Synthetic Diamond Abrasives (SDA)". It is used for sawing, drilling or milling hard stones, etc. In general, large crystals are used for cutting softer materials. Small crystals are used normally for tougher material.

With regard to apatite, mining and processing waste contains uranium and fluorine. Some fluorine recovered during processing as H_2SiF_6 is used largely in municipal water treatment. Even if by-product uranium is recovered, other products remain in the waste. Random accumulations were observed in reclaimed lands. This problem has been solved by installation of adequate ventilation. Phospho-gypsum, a waste material formed during the production of superphosphate and other fertilizers is similar to gypsum except that it contains about 1% P_2O_5, 1% F and 10-30 times more radon, none of which is desirable. As per ruling by Environment Protection Agency (EPA) of United States of America in 1989, phospho-gypsum is unsuitable for sale as common gypsum. Production of each tonne of P_2O_5 yields about 5 tonnes phospho-gypsum. Phospho-gypsum waste is stored in large pipes known as gyp stacks that must be underlain by an impermeable clay layer and plastic liner and they have to be covered with plastic membrane to retard escape of radon and leaching by groundwater. Water used to transport gypsum slurries to the gyp stacks becomes acidic, having highly dissolved solid and must be recirculated to the plant or treated with lime before being released. The use of phosphate has also come under scrutiny. Much attention has been given to its role in stimulating the growth of algae and other organisms in surface water, the process known as entrophication. This can be a deleterious process if it causes blooms of algae which consume dissolved oxygen when they die. The process is widespread in lakes near populated areas and is even observed in shallow, isolated arms of the ocean. Phosphate fertilizers are probably not the only cause of phosphatic-induced entrophication. Fertilizer phosphate does not leach readily from the soil, partly because it is absorbed on to clay minerals or combines with any soil water to form apatite. One of the best ways to remove this phosphate is through the addition of lime which causes precipitation of apatite although the procedure is costly and has not been applied widely. Instead, the use of phosphate in detergents has been discouraged.

The mining of granite started initially in the bouldery zones present in the form of small hillocks. Earlieer, these hillocks were generally barren except small shrubs and bushes. The blocks were either trimmed in the hillocks themselves or were brought down the slopes and trimmed at the foothills. The rubble generated was utilized for the local construction or road building. Thus, during these operations, there was a little damage to the environment. As the mining progressed and more and more blocks of huge sizes were required to meet the demand, the sheet rock was approached by making cut in the ground by removing of topsoil or overburden. At this stage, the environment was intervened and general degradation of environment was observed. Environmental problems are similar to any opencast mining operation. The processing of granite requires huge quantity of water for cutting and polishing and in some

cases, kerosene and limewater is used as coolant for cutting purpose. Although most of the kerosene and lime is recycled, there are always chances of mixing these coolants with natural watercourses. Sludge, which is generated during cutting needs proper disposal. If sludge is allowed to flow with the waterways, it increases silting and pollutes water. The general degradation of land due to unscientific and selective mining is a common feature. Owing to paucity of land in leased area, the overburden consisting of soil and weathered material is being dumped in a disorganised manner in nearby fields, waterways, etc., creating hindrance to cultivation and waterways. The blasting and movement of heavy vehicles generate dust and thus air and noise pollution occurs.

In India, bauxite is mined by opencast method. Dust is generated as a result of drilling, blasting, loading, transportation operations, crushing and grinding of the ore. Bauxite ore extracted freshly is known to be chemically active and is attacked easily by atmospheric oxygen, heat, moisture and micro-organism. Rainwater draining through ore piles turns acidic and dissolves metals which may affect eventually both groundwater and surface water bodies. Pollution is also caused by fluoride emission from aluminium smelters, emission of coal dust from steam generators, alumina dust from calcining plant, sulphur dioxide emission from refinery and red mud generated during alumina refining. Careful monitoring of the quality of air and groundwater as well as surface water resources are therefore necessary in and around mining areas. In mechanized mine, compressed-air-powered drill for drilling blastholes, power shovels or excavators for ore/overburden handling and trucks and dumpers for transporting the ore and overburden handling are used. Separate benches are maintained for the overburden and ore body. The height of benches in ore varies from 1.5 to 7.5 m. In a number of mines, operations are semi-mechanised, but handling of ore is manual. Machinery is deployed generally in overburden. Wherever bauxite occurs as small lenses or pockets or as segregations in murrum and laterite, it is difficult to mechanise the mining operations. Many bauxite mines are small and are worked manually. A Ripper Dozer silently ploughs the mine surface to extract the mineral. It has totally eliminated the ground vibrations and air pollution normally caused by dust, gases and noise.

Corundum of industrial grade produced in Madhya Pradesh is sent to the abrasive factory at Hanumana in Rewa district. The semi-precious varieties are recovered along with industrial grades in Bhopalpatnam in Bastar district of Chhattisgarh. After washing, stones are hand-picked and sorted out by visual observation considering their ability to take polish.

The principal use of corundum is in abrasives, such as grinding wheels, papers and clothes, and grinding powder.[5] The resources of quartz and silica sand are quite extensive.

For silica minerals, mining is carried out by opencast method. Quartz produced in the form of lump along with other associated minerals is invariably crushed into pieces and hand-sorted before it is dispatched to the consuming industries. Glass sand is generally screened and washed to remove all the deleterious constituents for its use in glass industry. Gujarat Mineral Development Corporation Ltd. (GMDC), one of the leading producers of silica sand in the country, produces silica sand in different mesh sizes by grinding and screening in its plant at Surajdeval, Surendranagar district, Gujarat. Andhra Pradesh Mineral Development Corporation Ltd. (APMDC) has two crushing plants at Mahaboobnagar district, having crushing capacity of 45 tonnes and 1,000 tonnes a month, respectively. Besides, Maharashtra Minerals Ltd. has a 50,000-tonne per year beneficiation plant in Sindhudurg district. If dumped improperly after drying, fine particles get dried and mixed up with air, causing serious breathing problems. Towards mitigation, guidelines for the conservation of environment during granite mining and processing have also been spelt out in Granite Conversion and Development Rules,1999 (GCDR,1999).[5] The respirable silica continued to cause main concern to miners and consumers since many minerals contain "crystalline silica", especially in industrial sand and gravel. There is a potential threat of "silicosis" to the workers in the quartz, silica sand and gravel mines. In the USA, the Occupational Safety and Health Administration (OSHA) listed "crystalline silica" as one of top five priorities for formal rule-

making. The OSHA, based on significant information in 'International Agency for Research of Cancers' evaluation, has declared that any material containing more than 0.1% crystalline silica should indicate its carcinogenic hazard. In order to reduce the potential threat of "silicosis", a variety of materials are used as substitutes for silica. Basic and neutral refractories (including magnesite, magchrome, dolomite and high-alumina bricks) have replaced silica in a large number of applications. Chromite, olivine and zircon are alternatives to foundry sands, garnet and to a lesser extent, olivine is used in sand blasting to avoid the risk of silicosis. Wollastonite is a better choice than free silicon for use in the ceramic industry again due to the risk of silicosis. In the electronic industry, replacement of natural quartz crystal by cultured quartz crystal is increasing steadily. [5]

Felspar is chiefly worked from pegmatites. Mining is carried out generally by manual method. Most mines are opencast. Significant output of felspar is generated as an associated mineral during mining of quartz, mica and beryl. Important mining centers are clustered in Ajmer district, Rajasthan and Nellore district in Andhra Pradesh. As felspar occurs in association with other minerals, the topsoil and overburden are removed to expose pegmatites. It is then broken either manually or by drilling and blasting. The broken material is sorted out and sized. Crushing generally does sizing.

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