Role of Minerals as Engineering Materials for National Development

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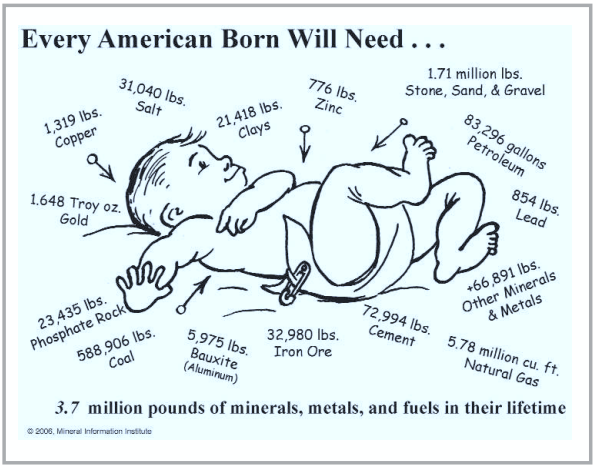
INTRODUCTION

Mining is about the digging and extraction of the minerals resources endowed by our good earth and using it to generate wealth, provide for the needs of mankind, and improve their living standards and quality of life. In Paleolithic Age, rock tools enable man to hunt and eat better. In Neolithic Age, clay bowls and pots provided man with basic utensils. In Metal Age, man learns to turn ore into metals leading to the development of better tools, utensils and weapons. In this Modern Age, man has developed minerals for a diversity of uses enabling us to enjoy the development, facilities, products, comfort and quality of life today. The baby drawing shows an estimate of the amount of minerals consumed by an American in his or her lifetime.



The statement "If it cannot be grown, it has to be mined" reminds us that all our material needs comes from our good earth, directly as minerals extracted from the earth or indirectly from plants and animals sustained by the earth. Engineers play a vital role to design, use, build and transform the earths' minerals and plants into structures and products to serve the needs of mankind.

When the word mining is mentioned in Malaysia, many people perceive that it is no longer active with the slowdown of tin mining following the tin crisis in 1985. Although interest in tin mining has revived with the surge in tin price, mining in Malaysia is not about tin mining alone. Besides tin, there are gold, iron and coal mines. There are also more than 2400 mining and quarrying operations producing aggregates, industrial minerals and earth material in Malaysia. At the National Seminar on Minerals 2006, the Ministry of Natural Resources and Environment announced that Malaysia has mineral reserves valued at RM 148 Billion.

Minerals are essential assets of a nation. It provides the basic materials for development, to generate wealth and the growth of mineral based industries. Engineers are builders of the nation and minerals provide the engineers with the materials needed for nation building. To illustrate the role of minerals as engineering materials for National development, I made a simplistic grouping of minerals by usage into five major areas namely construction minerals, infrastructure minerals, metallic minerals, industrial minerals and energy minerals.

CONSTRUCTION MINERALS

Concrete

Buildings are the most obvious indicator of development and concrete is the most widely used engineering material. According to the World Business Council for Sustainable Development, concrete is only second to water as the most consumed substance on earth, with nearly one tonne of concrete used annually for each person on the planet. Concrete is a mixture of aggregates, sand and cement. Aggregates come from rocks. Sand is mainly the mineral quartz. Cement is made from limestone, shale/clay, iron ore and gypsum. In 2004, seventy three million tonnes of aggregates worth RM 950 million was used in engineering constructions. Taking our population as 25 million, the per capita consumption of aggregates in Malaysia is about three tonnes. Granite is the main rock type quarried, contributing about 70 per cent of the total aggregates produced, followed by limestone which constituted 15 per cent and other rock types like sandstone, andesite, diorite, basalt, dolomite and gabbro making up the rest. As an engineering material, the aggregates must be of the right rock type, quality and shape to produce concrete of the required strength and optimal mix design. Sand is a seemly abundant cheap material which is sometimes taken for granted. Kuala Lumpur is built on former tin mining areas where mining sand is cheap and easily available. Sources of mining sand in the Klang Valley is almost depleted or sterilised and now the construction industry has to get sand from further away places like Batang Berjuntai in the north or maybe in future from the state of Perak. States without ex-mining sands have to mine and wash sand obtained from rivers or sand deposits incurring higher production cost. In 2004, more than eighteen million tonnes of sand and gravel valued at RM 195 million was produced and used. Malaysia has 15 cement plants, including 8 integrated plants producing cement and clinker. Limestone and shale, the major ingredients for clinker manufacturing is sourced locally whereas gypsum has to be imported. In 2004, a total of 19.9 million tonnes of limestone valued at RM 136 million was used for the manufacturing of cement. Steel, an essential material for reinforced concrete is produced directly or indirectly from iron bearing minerals.

Brick walls, roof tiles and partitions

Bricks are the building blocks in a nation. The construction industry in

Figure 1: One of the many quarries producing aggregates for the construction industry

Malaysia uses billions of pieces of bricks and roof tiles each year. Bricks may be clay bricks, cement bricks or calcium silicate bricks. Clay bricks are made by moulding, drying and firing of suitable types of clay or shale. In 2004, some six million tonnes of clay valued at RM 80 million is consumed, a large portion of it used for the making of clay bricks. Most roof tiles are made from clays or cement based materials. Plasters for brick walls are made of prepared sand, lime, and cement.

Minerals provide us with material for making partitions and ceiling boards. Most partition and ceiling panels are made of gypsum or cement based materials. If heat insulation is required rock wool is added. Rock wool is spun from molten rocks like basalts or andesites.

Natural Stones, Tiles and Sanitary Wares

The beauty of all buildings and houses is greatly enhanced by paving the floors, walls and facades with natural stones or ceramic tiles. Rocks for dimension stones are selected based on aesthetic qualities like colour and design variations and physical properties like durability, friability and degree of absorption of oil or water. Common natural stones used are granites and marble obtained from local resources and supplemented with imported stones to increase variety and colour.

There is a vibrant ceramic tile industry in Malaysia with an annual production capacity of 72 million square metres. The ceramic tiles producers depend on local resources of clays, kaolin, silica, limestone as their raw materials. Currently, most of the feldspar used by the ceramic tile industry is imported but local feldspar resources are being developed.

Sanitary wares are important accessories for a building. Toilets, previously the back-room utility of a house are now being turned into rooms of beauty and luxury, especially for hotels and residential houses. This is made possible by the variety of decorated tiles and quality sanitary ware. Most sanitary wares are ceramic products produced by local companies using specially prepared clay bodies.

INFRASTRUCTURE MINERALS

Another indicator of development of a country is its infrastructures like roads, highways, railways, ports, and water and electricity supply systems. The construction of roads requires millions of tonnes of suitable rock and earth material supplied form nearby quarries and sand resources. If suitable, some fill materials for roads may be obtained from hills or higher grounds within the site that have to be leveled or cut saving huge amounts in material, transportation and royalty cost. Road base material, crusher run, aggregates, and premix have to be supplied from quarries and premix plants. Aggregates for road pavements has to fulfill specifications of soundness, fines content, flakiness, water absorption, impact values, crushing values and abrasion values. Development of quarries and premix plants usually follow large infrastructure projects as without them, infrastructure projects cannot go on.

Elevated highways, flyovers, bridges and ports are massive structures using millions of tonnes of steel, rocks, sand and cement.

Adequate water and electricity supply is essential for national development. Generation of hydro-electric power involves building of dams. The construction of dams require large volumes of rock and earth for building up the core and bulk of the dams and concrete for building the supporting and surrounding structures. The engineer has to find and use nearby borrowed material, understanding their properties and behaviour and also the surrounding ground condition to come up with the optimal design and construction. Some operating hydro-electric dams are at Kenyir, Bersia, Temenggor, Kenering and Pergau. Dams are also built for water supply and irrigation, the most currents ones being the Sungai Selangor Dam and Kinta RCC (Roller Compacted Concrete) Dam

Engineers are not only able to create lakes in land but also land in water. Land reclamation is active in the west coast of Malaysia and large volumes of sand and rocks are required. Mineral sand that fulfill granulometric specifications is dredged from the sea for land reclamation. Without adequate sand resource, it has either to be imported or reclamation cannot be done. Armour rocks for land reclamation and coastal protection come from quarries, preferably coastal quarries. Besides sand, there are other mineral resources in the sea which can be mined.

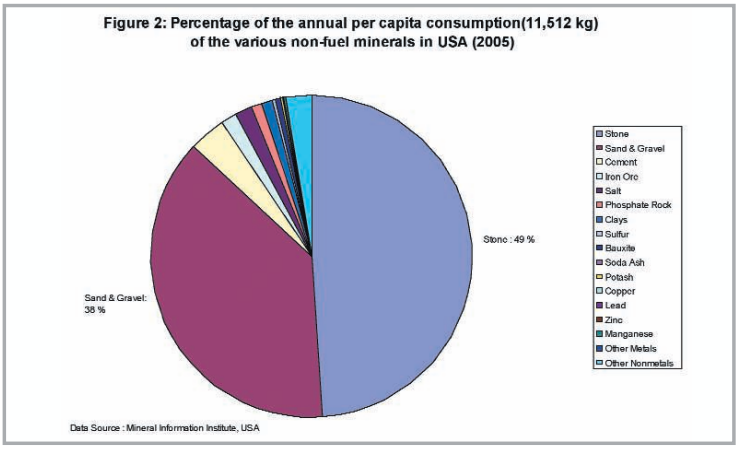


Figure 2: Percentage of the annual per capita consumption (11,512kg) of the various non-fuel minerals in USA (2005)

The annual per capita consumption of non fuel minerals (2005) in the United States of America was 11.5 tonnes (MII, USA). The percentage consumption of different minerals is shown in Figure 2. The major consumption is of aggregates, sand and gravel, making up about 87 % of the total. Mineral consumption figures in a developing country like Malaysia are lower, but the importance of minerals for human and national development remains the same.

METALLIC MINERALS

The most glamorous metallic mineral is gold and the most utilised is iron ore and Malaysia is lucky to have both of these mineral resources. Malaysia produced 4.22 tonnes of gold in 2004. Our iron ore resource is small by world standards producing 660,000 tonnes in 2004 for local consumption and exports. The total consumption of steel in Malaysia in 2004 was 7.8 million tonnes obtained from smelting imported ore and scrap iron. Iron ore minerals provide the basic raw material for industrialisation and man engineered it into different forms and products.

The use of aluminium is fast catching up as it has high strength-to-weight ratio, is an effective conductor of electricity and can be extruded, cast, drawn or rolled into thin sheets with thickness of as little as 7 thousandth of a millimeter. Aluminium is obtained from bauxite ore and Malaysia has some potential resources. Currently, Malaysia does not have an aluminium smelter and unwrought aluminium is imported for use by industries. There is keen interest for setting up aluminium smelting plants in Malaysia. These are multibillion Ringgit projects using huge amounts of electricity and can bring about the development of downstream aluminium product industry.

Tin, previously one of the pillars of our nation's economy, contributed greatly to the development of Malaysia. Our tin asset in the ground was developed and converted into other assets like the infrastructure, manpower and economic advancements which are the foundations for our prosperity today. Although tinplates have lost some grounds to aluminium in the packaging industry, tin usage, especially in lead free solder, has increased greatly to provide the strong cohesive bonding required by the solder and electronic industry. The use of organotin and tin chemicals to improve properties of engineering material has also increased sharply. Tin is seen as a "green" environmentally friendly metal. The present world annual consumption of tin is about 300,000 tonnes, greater than that before the tin crisis of 1985.

The usage of metals as an engineering material or modifier of properties of material is too far and immense to be mentioned here. New composite materials and products are continuing being developed. Some uses of metals and minerals are listed in Table 1.

INDUSTRIAL MINERALS

Non metallic minerals also play a major role in providing raw materials for industries. Limestone, marble, kaolin, plastic clays, common clays, sand, silica, mica and feldspars provide the necessary raw materials for Malaysia's mineral based industries. The production value of mineral based downstream industries was estimated at RM 15.7 billion in 2004.

Limestone provides the raw material for making cement, quicklime, hydrated lime and fillers which goes into the construction, steel and manufacturing industry. Kaolin provides the raw material for white cement, fiber glass, refractories, ceramic products and fillers. Fillers go into the paper, paint, rubber, plastic and pharmaceutical industries. Fillers used to

Table 1: Common uses of mineral products

Aggregates	Concrete, building construction, roads, bridges, dams, sewer and water systems
Aluminium	Aircraft parts, automotive parts (truck and automobile engine blocks and cylinder heads, heat exchangers, transmission housings, engine parts and automobile wheels), railroad cars, seagoing vessels, packaging (foil, cans, cookware), building construction (siding, windows, skylights, weather-proofing, doors, screens, gutters, down spouts and hardware), electrical applications (overhead power lines, wires and cables),pharmaceutical uses (antacid, antiperspirants), water treatment
Antimony	Alloys, flame-proofing compounds, batteries, plastics, ceramics, glass, infrared detectors and diodes, cable sheathing, small arms, paints, medicine
Chromium	Metal plating, alloys, pigments, corrosion resistance, glass and ceramics, catalyst, oxidising agents, anodising aluminium, tanning leather, refractory products
Clays	Bricks, sewerage pipes, pottery, tiles, sanitaryware, tableware, ceramics, nutritional additives, concrete, mortar
Coal	Electricity generation; steel making; chemical manufacture; production of liquid fuels, plastics and polymers
Copper	Building construction (wire, cable, plumbing and gas tubing, roofing and climate control systems), aircraft parts (undercarriage components, aeroengine bearings, display unit components, and helicopter motor spindles), automotive parts (wire, starter motor, bearings, gears, valve guides), industrial applications and machinery (tools, gears, bearings, turbine blades), furniture, coins, crafts, clothing, jewellery, artwork, musical instruments, cookware
Dolomite	Building stone, glass, soil conditioner, nutritional additives
Feldspar	Glass, ceramics, enamel, tile glazes, source of alkalies and alumina in glazes, paint, plastics, mild abrasives, welding electrodes
Fluorspar	Steel making, aluminium, fluorocarbons (used in refrigerants, blowing agents, solvents, aerosols, sterilants, fire extinguishers)
Gold	Ornamental, electronics, dentistry, decorative plating of costume jewellery, watchcases, pens and pencils, spectacle frames and bathroom fittings, decoration of china and glass
Graphite	High-temperature lubricants, brushes for electrical motors, brake and friction linings, battery and fuel cells, pencil fillings, seals and gaskets, conducting linings on cables, antistatic plastics and rubbers, heat exchanger, electrodes, apparatuses and linings for the chemical industry
Gypsum	Building construction (plasterboard, plaster and cement), agriculture, glass, chemicals Iron Steel making, alloy
Kaolin	Filler for paper, rubber, plastic, paint, fertilisers and adhesives, refractories, ceramics, fibreglass, cement, catalyst for petroleum refining
Lead	Batteries, cable sheathing, lead crystal, solder and radiation protection, antiknock compound in petrol, plumbing, ammunition
Limestone	Aggregate, cement, fertiliser, soil conditioner, iron flux, paints, filler for paper, rubber and plastics, livestock feed, lime chemicals, building stones
Manganese	Steel making, alloys, batteries, colourants and pigments, ferrites, welding fluxes, agriculture, water treatment, hydrometallurgy, fuel additives, oxidising agents, odour control, catalysts, sealants, metal coating, circuit boards
Magnesite	Agricultural fertiliser, refractory bricks, filler in plastics and paints, nuclear reactors and rocket engine nozzles, manufacture of Epsom salts, magnesia, cosmetics, insulating material and disinfectant, fire retardant
Magnesium	Alloys used for aircraft, car engine casings, and missile construction; refractory material; agriculture (feed and fertiliser); filler in paper, paints, and plastics; automobile and machinery; ceramics; fire retardant; pyrotechnics and flares
Nickel	Stainless steel, corrosion-resistant alloys, gas turbines, rocket engines, plating, coins, catalysts, burglar-proof vaults, batteries
Niobium	Alloys, stainless steels, advanced engineering systems (space programs), nuclear industry, electrical products, jewellery

Platinum	Jewellery, coins, autocatalysts, electronics, glass, dentistry, chemical and electrochemical, catalysts, petroleum, laboratory equipment, antipollution devices in cars, investment, anti-cancer drugs, implants (pacemakers, replacement valves)
Pumice	Construction, stonewashing in textile industries, glass and metal polishing, dental supplies and paste, agriculture, sport and leisure facilities, cosmetics
Sand and gravel	Concrete, bricks, road premix, roads, bridges, dams, land reclamation, building materials
Silica	Glass (flat, tempered, laminated, optical, bottles and jars), foundry sand, sodium silicate, silicon wafers
Silver	Photography (X-ray film for medical, dental, industrial uses), jewellery, electrical applications, batteries, solder and brazing alloys, tableware, mirrors and glass, coins
Soda ash	Glass, detergents, chemicals, water treatment, flue gas desulphurisation, pulp and paper
Sulphur	Sulphuric acid, ammunition, fungicide, vulcanisation of natural rubber
Talc	Paper, plastics, paints, ceramics, refractories, roofing, rubber, cosmetics, pharmaceuticals, agrochemical, animal feed, cement, glass fibre
Tantalum	Electrolytic capacitors, alloys (use in aircraft and missile manufacture), lining for chemical and nuclear reactors, wires, surgery (used in sutures and as cranial repair plates), cameras
Tin	Tinplates, alloys, solder, pewter, tin chemicals, organotin, stabilisers, frost-free windshields
Titanium	Production of lightweight alloys, aircraft components (jet engines, aircraft frames), automotive components, joint replacement (hip ball and sockets), paints, watches, chemical processing equipment, marine equipment (rigging and other parts exposed to sea water), pulp and paper processing equipment, pipes, jewellery
Tungsten	Alloys (used in filaments for electric lamps, electron and television tube, metal evaporation work), ammunition, chemical and tanning industry, paints, X-ray targets
Uranium	Nuclear fuel, nuclear weapons, X-ray targets, photographic toner
Zinc	Galvanising, alloys, brass, batteries, roofing, water purification, coins, zinc oxide (used in manufacture of paints, rubber products, cosmetics, pharmaceuticals, floor coverings, plastics, printing inks, soap, textiles, electrical equipment, ointments), zinc sulphide (used in making luminous dials, X-ray and TV screens, paints, fluorescent lights.
Zirconium	Ceramics, refractories, foundry sands, glass, chemical piping in corrosive environments, nuclear power reactors, hardening agent in alloys, heat exchangers, photographic flashbulbs, surgical instruments

be functional fillers, usually providing a cheaper alternative to built up a product but now fillers are moving toward performance fillers, engineered to enhance the property and quality of a product.

Clays provide the raw material for simple structural products like bricks, tiles and pipes to higher valued products like ceramic tiles, sanitary ware, tableware, art ware, formers, activated clays, bleaching agents, catalyst, refractories and advanced ceramic components. Sand provide the raw material for flat glass, panel glass, tempered and laminated glass, auto glass, container glass, tableware, optical glass, sodium silicate, foundry sand, filter sand and silicon wafers.

ENERGY MINERALS

Energy moves the wheels of the nation and fuel minerals form a major portion of the mineral requirements of mankind. It is estimated in USA that the per capita annual consumption of fuel minerals (including petroleum and gas) is 10 tonnes, making up about 47% of the per capita annual consumption of total minerals of 21.5 tonnes. Malaysia gets her energy for power generation from petroleum, natural gas, hydropower, coal and renewable sources. At present there are two power stations in Peninsular Malaysia using about 10 million tonnes of coal per annum and another smaller power station in Sarawak using about 300,000 tonnes of coal per annum. Two more coal fired power stations will be built in Johore and Negeri Sembilan and by 2010 the consumption of coal is expected to rise to 19 million tonnes per annum. Coal will play an increasingly important role to fulfill the increasing energy needs of Malaysia.

CONCLUSION

Nations well endowed with mineral resources are considered to be rich as mineral is a nation's asset. However, unless it is developed, it does not generate economic activity, wealth and national development. Minerals belong to the States so the Government together with engineers and other professionals should encourage and plan the optimal development, extraction and utilisation of mineral resources to bring maximum social and economic benefits to the people and nation.

Minerals, however, are non renewal resources, so they should be developed in a sustainable manner. The environmental impacts must be minimised and controlled during operations and the land returned for other land use after mineral extraction. While minerals play a major role and provide the material for national development, it is us professionals who can maximise the wealth creation, minimise the negative environment impacts and at the same time conserve our earth given mineral resource.

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