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RESEARCH ARTICLE

Identification of the most suitable rock types for manufacture of quarry dust in Sri Lanka

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Abstract: The construction industry of Sri Lanka expects a serious shortage of river sand in the near future due to over exploitation. As a result the construction industry will be affected unless suitable alternatives are found for river sand. Near shore marine sand, dune sand and quarry dust (crushed rocks) are the alternatives available in Sri Lanka. Quarry dust however may not be suitable for civil constructions since it is a mixture of various broken minerals. This study was initiated to determine the mineralogical composition of quarry dust.

Fresh rock samples from different quarries were collected for the laboratory tests. Thin sections were prepared from each sample and studied under the petrographic microscope. Mineral composition of each sample was determined using a point counting instrument attached to the microscope.

The main minerals present in fresh rocks are quartz, feldspar, biotite mica, hornblende and hypersthene. Few other minerals are also present as minor components. There are no reactive forms of silica minerals such as opal and chalcedony in these rocks. Hornblende biotite gneiss, biotite gneiss, migmatite and migmatitic gneiss have mica percentages higher than 5% (5%-20%). Mica percentage in charnockite, charnocktic gneiss and granitic gneiss is always less than 5%. Generally, sand with less than 5% of mica is considered to be suitable for civil engineering construction. Therefor, charnockite, and charnockitic gneiss and granitic gneiss rock quarries are suitable for supply of quarry dust to be used as an alternative for river sand.

Keywords: Concrete, metamorphic rocks, quarries, sand, Sri Lanka

INTRODUCTION

Throughout the history of the construction industry, river sand has been used as one of the major components of the building materials due to the ready availability and its well-graded nature with the sand grains of different sizes well distributed. River sand is mainly used for all kinds of civil engineering constructions. The annual sand demand for the construction industry is 9.4 million metre cubes[1]. It is assumed that the amount of sand removed from these rivers is three times more than the amount transported by these rivers. The excessive excavation for river sand is becoming a serious environmental problem in Sri Lanka. Intensive river sand mining results in failure of river banks, lowering of river beds, damages to the bridge foundations and other structures situated closer to the rivers, saline water intrusions and coastal erosion. As a result the Government has banned sand mining in some identified areas of major rivers. At present the construction industry in Sri Lanka is facing a severe shortage of sand due to the government banning of river sand mining. In the future the entire construction industry may come to a halt if there are no alternatives for river sand. Therefore, it is necessary to explore possible alternatives to minimize the use of river sand.

At present the identified alternatives are dune sand, offshore sand, manufactured sand (crushed rock sand) and quarry dust. Quarries are operating in many parts of Sri Lanka to supply coarse aggregates for various constructions, especially for concrete, road constructions and foundations of buildings. In Sri Lanka quarry dust has not been commonly used in place of river sand previously because of the differences in quality. Various rock types produce quarry dusts of different types with different qualities due to the inclusion of different minerals. Although it is now used for road works and manufacture of cement bricks the construction industry is afraid to use it for concrete and other strong constructions due to the high percentages of minerals other than quartz.

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Properties of quarry dusts mainly depend on the properties of the parent rock such as chemical and mineralogical composition, physical and chemical stability, petrographic characters, specific gravity, hardness, strength, pore-structures and colour. The quality of quarry dusts depends mostly on the mineralogical composition. Hence, a detailed study was carried out to determine the mineralogical compositions of different rock types in Sri Lanka and recommend the suitable rock types for the manufacture of quarry dusts.

Geologically nine tenths of the rocks in Sri Lanka are made up of high grade metamorphic rocks of Precambrian age i.e., older than 570 million years, belonging to one of the ancient and stable parts of the earth's crust, called the South Indian Shield. The remaining rocks are sedimentary rocks of predominantly Miocene age and are located in the north-west (and very few places of south east) with some Jurassic sediments preserved in small faulted basins. There are recent sedimentary formations, identified as Pleistocene Deposits in a few locations. Intruding the metamorphic rocks of Sri Lanka are some granites, dolerites, pegmatites, quartz veins and a carbonatite[2]. Charnockitic gneiss or charnockite, quartzite, marble, dolomite, granulite, migmatite, gneisses (garnet sillimanite graphite gneiss, hornblende biotite gneiss, biotite gneiss, calc gneiss, cordierite gneiss, wollastonite-scapolite gneiss, granitic gneiss) and amphibolites are the common Precambrian metamorphic rocks in Sri Lanka. The widely distributed rocks within the country are charnockite, hornblende biotite gneiss, biotite gneiss, migmatite and granitic gneiss. Most of these metamorphic rocks are very hard and strong.

The land surface of Sri Lanka has been subjected to a prolonged period of weathering and erosion under different climatic conditions. The secondary formations arising from weathering such as laterite, ferricrete, calcrete that are found throughout the island belong to the younger Pleistocene formations. Recent deposits include both residual and alluvial formations. Residual deposits include the deep weathered zones or soils to be found in the central hill country and in the intermediate slopes[3]. These deposits are not uniform in character and contain fragments of un-decomposed rocks[4, 5]. In some areas of the Wet Zone, the thickness of the weathered profile may go up to 50 meters. In general the thickness may be between 10-15 metres. Residual shallow weathered zones are mainly confined to the Dry Zone areas and the general thickness is less than 10 metres[6]. The weathering is not uniform in different places in the country and the thickness varies drastically from place to place. The thickness of the top residual soil layer may be from 40 cm to 150 cm.

In most places in the country the bedrocks are overlaid by residual soils, weathered rocks, alluvial deposits or colluvial deposits. But there are many exposed rocks available for the quarrying industry in the mountain areas as well as low level flat terrains in Sri Lanka. Industrial rocks and minerals such as limestone, marble, dolomite, apatite, graphite, mica, feldspar and quartz are used for lime and other different industries as well as for exporting purposes. Fresh outcrops of the other regional bedrocks are used for the construction industry. Metamorphic rocks such as gneisses, charnockite, migmatite, granulites, amphibolite and igneous origin granites are used for this industry. However, these weathered rocks are not used for concrete or cement mixed constructions.

METHODS AND MATERIALS

The quarries which are currently operating in the Central and North Western Provinces of Sri Lanka were selected for the first stage of the study. Quarries located very close to each other that use the same rock type were not selected for sampling. About 9" x 9" size fresh rock samples were obtained from different quarries for the laboratory studies.

The laboratory method BS812 Part 104 (1994) was used for petrographic examinations. The rock was cut into small slides using diamond rock cutting machine and polished on one sides of the sample using a grinding machine. Carborandom powder (silicon carbide) was used as the grinding material. The polished side of each sample was fixed to a glass slide using Epoxy glue. The other side of the sample was ground to obtain a standard thickness (0.03 mm). Using Canada bolsom glue, a cover slip was mounted over each sample. This method was repeated for all rock samples collected from different quarries. The prepared thin sections of rocks were used for microscopic studies (petrographic studies). The mineral composition of each sample was determined using a point counting instrument (point counter) attached to the microscope.

RESULTS

Table 1 shows the percentage amounts of the major minerals present in the different rock types in Sri Lanka. Quartz, feldspar, hornblende, hypersthene and biotite mica are the major minerals present in the widely distributed common metamorphic rocks in Sri Lanka. All other minerals including garnet were considered as accessory minerals. The quarry locations are also shown in Table1.

Table 1: Mineral composition of different rock types as percentage.

Rock type	Location	Mineral Percentage					
		Qtz	Feld	Hnb	Hyp	Biot	Oth
Bt-Gn	Denwar Estate, Mawathagama	72	12	-	-	14	2
Bt-Gn	Delgollawatte, Mawathagama	40	50	-	-	5	5
Mig-Gn	Hatpokuna, Kurunegala	40	48	5	-	5	2
HbBt-Gn	Medawela, Galagedara	28	20	45	-	6	1
HbBt-Gn	Medagama, Narammala	44	20	12	3	20	1
HbBt-Gn	Delgasyaya, Galagedara	46	27	11	-	15	1
Gr-Gn	Tittawelga, Kurunegala	34	63	1	-	1	1
Gr-Gn	Bogammana, Wariyapola	52	40	-	2	5	1
Gr-Gn	Pallandeniya, Kurunegala	40	57	-	-	2	1
Gr-Gn	Puingalla, Wariyapola	30	65	3	-	1	1
Chan-Gn	Welagedarawatte, Kurunegala	40	30	19	5	4	2
Chan	Elahera, Naula	65	18	6	10	-	1
Chan	Kosdeniya, Katupotha	30	50	5	10	4	1
Chan	Egodagama, Kurunegala	60	34	-	5	-	1

<u>Minerals</u>

Qtz = Quartz
Feld = Feldspar
Hnb = Hornblende
Hyp = Hypersthene
Bit = Biotite
Oth = Other minerals

<u>Rock types</u>

Bt-Gn = Biotite gneiss
Mig-Gn = Migmatitic gneiss and migmatite
HbHt-Gn = Hornblende biotite gneiss
Gr-Gn = Granitic gneiss
Chan-Gn = Charnockitic gneiss or charnockite

DISCUSSION

The common rocks used for the production of aggregates in Sri Lanka are hornblende biotite gneisses, biotite gneiss, charnockite and charnockitic gneiss, migmatite, and granitic gneiss. These are Precambrian metamorphic rocks, which are distributed regionally in most areas within the country unlike the Miocene sedimentary rocks and are not considered as sources of economically important minerals. The most common minerals in the sampled rocks are quartz, feldspar, hornblende, biotite and hypersthene. The rocks in almost all the quarries belong only to one of the above mentioned rock types. There are however one or two quarries with Pink Feldspar granite rocks of igneous origin. The other rock types present in Sri Lanka are not widely distributed and exist as narrow bands within the rocks.

Research data indicates that 5% content by mass of mica in sand reduces the 28 days strength of concrete by about 15% even when the water/cement ratio was kept constant[7]. Muscovite mica is more harmful than biotite mica. Sulfide minerals such as pyrites and marcasite react with water vapour and oxygen in the air to form a ferrous sulfate which subsequently decomposes to form a hydroxide. This hydroxide reacts with calcium aluminates in the cement and may form sulfuric acid which can attack the hydrated cement paste. In recent years an increasing number of deleterious chemical reactions between the aggregates and surrounding hydrated cement paste have been observed[8]. Here the most common reaction occurs between the active silica constituents of the aggregates and the alkalis in cement. The reactive forms of silica are opal, chalcedony and tridimite. Generally river sand containing less than 5% of mica is considered as suitable for civil engineering constructions[7]. Higher amount of mica reduces the workability due to its flakiness. The composition of quarry dust depends on the mineral composition of the parent rock. It may also depend on the type of crusher and its reduction ratio, i.e. the ratio of the size of the material fed into the crusher to the size of the finished products. There are no reports available on the effects of crushers on the manufacture of rock aggregates.

Table 1 shows the distribution of major minerals in the rocks of the study area based on petrographic examination of parent rocks. Similar mineralogical mixtures can also be expected in the fine to coarse grained size quarry dusts. As mentioned earlier the common rock types used for the production of aggregates in Sri Lanka are hornblende biotite gneisses, biotite gneiss, charnockite and charnockitic gneiss, migmatite, and granitic gneiss. In these Sri Lankan metamorphic rocks concentrations of opal, chalcedony and tridimite are almost nil but medium to coarse grained biotite mica mineral is always visible in most of the rocks except Quartzite. Pyrite may occur as an accessory mineral in metamorphic rocks but the total opaque mineral percentage in each rock type is less than 5%.

The results in Table 1 clearly indicate that the amount of mica percentage is higher than 5% (5%-20%) in hornblende biotite gneiss, biotite gneiss, migmatite and migmatitic gneiss. Mica percentage in charnockite, charnocktic gneiss and granitic gneiss is always less than 5%. Accordingly charnockite, charnockitic gneiss and granitic gneiss may be suitable rock types to obtain quarry dusts (in addition to the coarse aggregates) for use as an alternative to river sand in the future. However, the crushing strength of charnockite and choarnockitic gneiss is much higher than the gneisses[9]. Therefore, manufacturing of quarry dust from charnockite may take longer than from granitic gneiss. The mica percentage may vary from place to place even within the same rock such as hornblende biotite gneiss. Therefore, petrographical and mineralogical examinations are needed for each quarry to find out the quarry dust quality.

Quartzite is a rock without mica. Therefore, it may be the best rock for the manufacture of fine aggregates for the construction industry. But generally quartzite is not used as a coarse aggregate for concrete or for building roads and quarry dust cannot be obtained from quartzite. Most of quartzite rocks at the surface are slightly weathered. Fresh quartzite (or referred as vein quartz) is successfully used for some other industries in Sri Lanka and abroad.

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References

1. Delft Hydraulic and Netherlands Economic Institute (1992). Draft final report, volume 1, National Sand Study for Sri Lanka-Phase one. Delft, The Netherlands.
2. Vitanage P.W. (1970). A study of the geomorphology and morphotectonics of Ceylon, *Proceedings of the Second Seminar on Geological Prospecting Methods and Techniques,* New York. pp.391-405.
3. Cooray P.G. (1967). *An Introduction to the Geology of Ceylon*, first edition Department of National Museums, Government Press, Colombo.
4. Herath J.W. (1963). The mineralogical composition of some laterites and lateritic soils of Ceylon. *Industrial Minerals* **4**:36-42.
5. Herath J.W. (1963 a). Kaoline in Ceylon. *Economic Geology* **58**:769-773.
6. Kandy District Water Supply and Sanitation Project (KDWSSP) (1985). *Interim Report* on the groundwater resources in Kandy district, Kandy District. Water Supply and Sanitation Project, Kandy.
7 Fookes P.G. & Revie W.A. (1982). Mica in concrete – a case history from Eastern Nepal. *Concrete* **16** :12-16.
8. Neville A.M. (1995). *Properties of Concrete*, first edition Longman Group Limited, England.
9. Jayawardena U.de S. (2001). A study on the engineering properties of Sri Lankan rocks. *Journal of the Institution of Engineers* of Sri Lanka **XXXIV** (02): 07-22.