Use of quarry dust instead of river sand for future constructions in Sri Lanka

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Abstract: The construction industry of Sri Lanka expects a serious shortage of sand in the near future due to over exploitation of river sand. Then, the entire construction industry will be paralyzed if there are no alternative sources instead of river sand. Near-shore marine sand, dune sand and quarry dust (crushed rocks) are the other alternative sources available for it in Sri Lanka. Quarry dust may not be suitable for the civil constructions due to the mixture of various broken minerals. Hence, research was initiated to find out the mineralogical quality of the 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 counted using a point counting instrument attached to the microscope.

The minerals present in fresh rocks were quartz, feldspar, biotite mica, hornblende and hypersthene as major and a very few other minerals as minor. There are not any reactive forms of silica minerals such as opal and chalcedony in these rocks. Hornblende biotite gneiss, biotite gneiss, migmatite and migmatitic gneiss showed mica percentages higher than 5% (5%-20%). Mica percentages in charnockite, charnocktic gneiss and granitic gneiss are always less than 5%. Generally, sand with less than 5% of mica is considered as suitable for civil engineering construction. Therefore, charnockite and charnockitic gneiss and granitic gneiss are suitable rocks to operate as quarries and supply quarry dust to use as an alternative source for river sand in the future.

Résumé: L'industrie du bâtiment du Sri Lanka s'attend à un manque sérieux du sable dans le futur proche dû à l'exploitation finie du sable de fleuve. Alors l'industrie du bâtiment entière sera paralysée s'il n'y a aucune source alternative au lieu du sable de fleuve. Près du sable marin de rivage, la poussière dunaire de sable et de carrière (pierres concassées) sont les autres sources alternatives disponibles pour lui au Sri Lanka. La poussière de carrière peut ne pas convenir aux constructions civiles dues au mélange de divers minerais cassés. Par conséquent une recherche a été lancée pour découvrir la qualité minéralogique de la poussière de carrière.

Des échantillons frais de roche provenant de différentes carrières ont été rassemblés pour les essais en laboratoire. Des sections minces ont été préparées à partir de chaque échantillon et étudiées sous le microscope pétrographique. La composition minérale de chaque échantillon ont été comptées à l'aide de l'instrument de compte de point fixé au microscope.

Les minerais actuels dans les roches fraîches étaient quartz, feldspath, mica de biotite, hornblende et hypersthene comme commandant et très peu d'autres minerais en tant que mineur. Il n'y a aucune aucune forme réactive de minerais de silice tels que l'opale et le chalcedony dans ces derniers bascule. Le gneiss de biotite de hornblende, le gneiss de biotite, le migmatite et le gneiss migmatitic ont montré le pourcentage plus haut que 5% (5%-20%) de mica. Le pourcentage de mica en charnockite, gneiss charnocktic et gneiss granitique est toujours moins de 5%. Généralement le sable consiste à de 5% de mica est considéré comme approprié au génie civil. Par conséquent le charnockite et le gneiss de gneiss et granitique charnockitic conviennent les roches à fonctionner comme carrières et pour fournir la poussière de carrière à l'utilisation comme source alternative pour le sable de fleuve à l'avenir.

Keywords: aggregate, concrete, metamorphic rocks, sand, properties, quarries.

INTRODUCTION

Ever since the history of the construction industry began, river sands have been used as the major building material component. This is due to the ease of acquisition and its well-graded nature and that all sizes of grains are well distributed in a given sample. The application of river sand is mainly for all kinds of civil engineering construction. The annual sand demand for the construction industry in Sri Lanka is nearly 8 million cubic metres and all is obtained from major rivers. This present demand is expected to be 10 million cubic metres within next three years. It is assumed that the removal rate of sand from these rivers exceeds by three times the annual transport rate of these rivers. The excessive excavation of river sand is becoming a serious environmental problem in Sri Lanka. Erosion and failure of river banks, lowering of river beds, damage to the bridge foundations and other structures situated closer to the rivers, saline water intrusion into the land and coastal erosion are the major adverse effects due to intensive river sand mining. 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 serious shortage of sand due to overexploitation and government banning of river sand mining. In the future, the entire construction industry may come to a halt if there are no alternative sources instead of river sand. Therefore, it is necessary to explore the possibilities for alternative sources to minimize river sand extraction.

At present, the identified alternative sources 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 types of construction, especially for concrete, road construction and foundations of buildings. The quarry dust, the by-product, was never used in Sri Lanka instead of river sand earlier because of the different quality. Various rock types produce different types or different qualities of quarry dusts due to the inclusion of their fresh minerals. Aslo, it has no uniformity and similarity to river sand. Although now it is used for road works and manufacture of cement bricks the industry people are afraid to use it for concrete or such strong constructions due to the higher percentages of minerals other than quartz. Therefore, detailed studies on various quarry dusts are needed to find out their suitability.

Properties of quarry dust mainly depend on the properties of the parent rock such as chemical and mineralogical composition, physical and chemical stability, petrographic characteristics, specific gravity, hardness, strength, pore structures and colour. As far as quarry dust quality is concerned, the most important property is the mineralogical composition. Hence, a detailed study was carried out by the authors to determine the mineralogical compositions of different rock types in Sri Lanka. The objective of this paper is to present the mineralogical quality of different-common rock types and recommend the suitable rock types for the manufacture of quarry dusts in the future.

GENERAL GEOGRAPHY AND GEOLOGY OF SRI LANKA

Sri Lanka is an island in the Indian Ocean lying between latitudes 5^0 and 10^0 north and longitudes 79^0 and 82^0 east (Figure 1). It is situated 32 km east of the southern tip of India separated by Palk Strait and the Gulf of Mannar and 880 km north of the Equator. The total land area is 65,610 square kilometres. Physiographically, Sri Lanka consists of a central mountainous mass or central highland surrounded by a low, flat plain on all sides and extending to the sea (Vitanage 1970). Sri Lanka is considered to have a humid tropical climate. The mean annual rainfall for the Island is 2030 mm. The temperature in the country generally lies between 14^0 C and 32^0 C. On the basis of rainfall, the dryness and topography, Sri Lanka can be divided into three climatic zones namely the Dry Zone (rainfall less than 2000 mm), the Intermediate Zone (rainfall between 2000 and 3000 mm) and the Wet Zone (rainfall above 3000 m) (Walker 1962).

Geologically, nine tenths of Sri Lanka is 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 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 (Cooray 1967). 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. These rocks have been formed under the granulite facies or amphibolite facies of regional metamorphism or under re-metamorphism. 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. Therefore, they weather very slowly.

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. These deposits are not uniform in character and contain fragments of un-decomposed rocks (Herath 1963a & b). In some areas of the Wet Zone, the thickness of the weathered profile may be up to 50 metres. 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 (KDWSSP 1985). The weathering is not uniform in any place in the country and the thickness changes drastically from place to place. The thickness of the top residual soil layer may be from 400 to 1500 mm.

In most of places in the country the bedrock is overlain by residual soils, weathered rocks, alluvial deposits or colluvial deposits. However, there are many exposed rocks available for the quarrying industry in the mountain areas as well as on the low level flat terrains. Industrial rocks and minerals such as limestone, marble, dolomite, apatite, graphite, mica, feldspar and quartz are using 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 using for this industry. However, the weathered rocks of these rocks are not used for concrete or cement mixed constructions.

METHOD OF STUDY

The quarries which are operating now in the central and north central provinces of Sri Lanka were selected for this first stage of the study. Although there are many quarries, those with the same rock type within a very short distance were not selected for sampling. About 230 mm x 230 mm size fresh rock samples were obtained from different quarries for the laboratory studies. All the laboratory studies were carried out at the Peradeniya, University, Peradeniya, Kandy city (Figure 1).

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

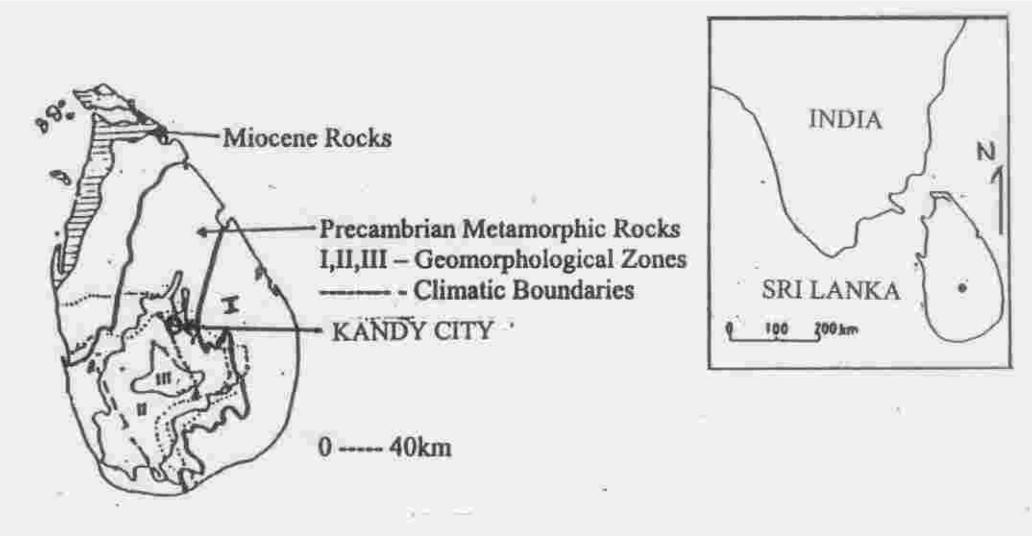

Figure 1. Location ok Kandy City, Sri Lanka

RESULTS

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	10	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	50	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

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

Rock types
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 using for the production of aggregates in Sri Lanka are hornblende biotite gneisses, biotite gneiss, charnockite and charnockitic gneiss, migmatite, granitic gneiss and granites. These Precambrian metamorphic rocks which are regionally distributed in most of the places except in Miocene sedimentary rocky areas (10%) (Figure 1). The most common minerals in these examined rocks are quartz, feldspar, hornblende, biotite and hypersthene. Generally, almost all the quarries belong to one of these rock types. There are one or two quarries of igneous origin, pink feldspar, granite rocks. The other rock types available in Sri Lanka are not widely distributed and exist as narrow bands within the regional rocks. Therefore studying the mineralogical compositions for the purpose of obtaining quarry dust in other rocks is meaningless.

Engineering research carried out by various scientists and engineers have predicted 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. Muscovite mica is much more harmful than biotite mica. Sulphide minerals such as pyrites and marcasite react with water and oxygen in the air to form a ferrous sulphate, which subsequently decomposes to form a hydroxide. This hydroxide reacts with calcium aluminates in the cement and may form sulphuric acid, which can attack the hydrated cement paste (Neville 1995). In recent years, an increasing number of deleterious chemical reactions between the aggregates and surrounding hydrated cement paste have been observed. 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, the river sand with less than 5% of mica is considered as suitable for civil engineering construction (Neville 1955). Higher mica percentage reduces the workability due to its flakiness.

The composition of quarry dust depends on the mineral composition of the parent rock. But 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.

Table 1 shows the distribution of major rock forming minerals in the rocks of the study area. This is the observations and results of the petrographic examination of parent rocks. Similar mineralogical mixture can be expected in the fine to coarse grained size quarry dusts also. In the Sri Lankan metamorphic rocks the concentration 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 minerals percentage in each rock types is less than 5%.

The results in Table 1 clearly indicate 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 rocks to operate as quarries for the purpose of supplying quarry dusts (in addition to the coarse aggregates) to use as an alternative source instead of river sand in the future. However, the crushing strength of charnockite and choarnockitic gneiss is much higher than the gneisses (Jayawardena 2001). Therefore, manufacturing of quarry dust from charnockite may take longer than granitic gneiss. However, the mica percentage may vary from place to place even within the same rock such as hornblende biotite gneiss. Therefore, petrographical and mineralogical examinations should be needed for each quarry to find out the quarry dust quality even if the rock type is not suitable.

CONCLUSION

The results in Table 1 clearly indicate 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 rocks to operate as quarries for the purpose of supplying quarry dusts (in addition to the coarse aggregates) to use as an alternative source of sand in the future. Manufacturing of quarry dust from charnockite may take longer than granitic gneiss due to strength difference. However, testing of quarry dusts for each quarry is needed while it is producing.

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