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Engineering and Geological Evaluation of Rock Materials as Aggregate for Pavement Construction

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Abstract: Construction aggregate is one of the most abundant natural resources and one of the most widely used. These are the crushed and sized rock materials used in concrete and asphalt. Selecting the right aggregate material for pavement construction is imperative to overcome the frequent problem of pavement failure. It needs to resist extreme field conditions of loading and weather. These properties will need to be tested and assured before the road is built. An attempt is made here to study the geological and engineering properties of different rocks from Trivandrum. A variety of rock samples from different parts of Trivandrum are subjected to study petrographic, physical and strength parameters. The engineering studies conducted in simulated field conditions gives an idea about the physical and strength properties of the rocks. The result of the study gives the rock which has maximum favourable properties for use in pavement construction applications, out of the available ones in the study area.

Keywords: Charnockite, Garnetiferous Biotite Gneiss, Geologic and engineering evaluation, Quarry mapping.

I. INTRODUCTION

Rocks are defined as "the natural solid massive aggregates of minerals forming the crust of the earth". Those types of rocks or mineral fragments that can be used as an aggregate material in combination with other natural or artificial materials like cement or bitumen for preparing an ideally suitable road surface may be termed as road materials. The greater part of the body of a road is generally constituted by the aggregates, which are supposed to bear the main stress under all types of traffic without undergoing much surface abrasion. More than 90% of asphalt pavement and 80% of concrete pavement consist of construction aggregate [3]. The remainder is a binder such as asphalt or cement. Thus much importance is always attached to the selection of the right type of aggregates for ensuring stability and durability of road. This requires a thorough understanding of the properties that a good road aggregate should always possess and also a comprehensive knowledge of important rock types that are suitable for the use of source of these aggregates.

Most of the road aggregates are prepared from natural rocks. The properties of rock, from which the aggregates are formed, depend on the properties of the constituent mineral materials and the nature of bond between them. Mineral composition of rocks exposed at quarries is important, particularly at places where rock bodies are intensively migmatised. Segregation of micaceous minerals along the foliation planes and in pegmatite veins is detrimental while considering the quality of aggregate. Similarly, surficial weathering of rocks and alteration along joints and fractures need to be considered for producing good quality aggregate.

The primary objective of the study is to identify the geological and engineering properties of different road construction aggregates in simulated field conditions which are available in the quarries of Trivandrum. The test results of various properties of aggregates are analyzed for optimal use in pavement construction application.

The study also aims to develop a quarry information system in the GIS platform for the study area. Maps showing the location of quarries based on the aggregate mineral properties are prepared.

II. STUDY AREA

Thiruvanathapuram, the capital of State of Kerala is located at the southern most part of the State. The headquarters is the city of Thiruvananthapuram, which is also the capital city of Kerala. The district is situated between $8^0 17'$ N and $8^0 54'$N and $76^0 41'$E and $77^0 17'$E. The city is located at $8^0 30'$ N and $76^0 54'$E. The city corporation has an area of 214.74 km^2 .

A. Geology of the Study Area

The Archean crystalline rocks comprise Khondolite group, Charnockite group and Migmatite group, which forms the geological foundation of the area. Khondolite group is composed of garnetiferous biotite - sillimanite gneiss, with occasional bands of calc granulite and quartzite and constitutes the major rock type. Charnockite are acidic to intermediate in composition. Irregular patches of Khondolite veins of pegmatite and quartz are seen within

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the Charnockite. Pyroxene granulite occurs within the Khondolite dykes, but their distribution is restricted to the midland region of the study area. Thin and impersistent veins of pigmatites and quartz are very common, and many of the pigmatites have gained importance because of their gemstone (chrysoberyl) content [4]. Sedimentary formation of Mio - Pliocene age occurs as detached patches unconformably overlying the crystalline rocks, along the coastal tracts. Quarternary formation includes pebble beds (with ferrugenious sand stone and bands of clay), coastal sands and alluvium. The Teritaries and basement rocks of the midland are extensively latertised [4].

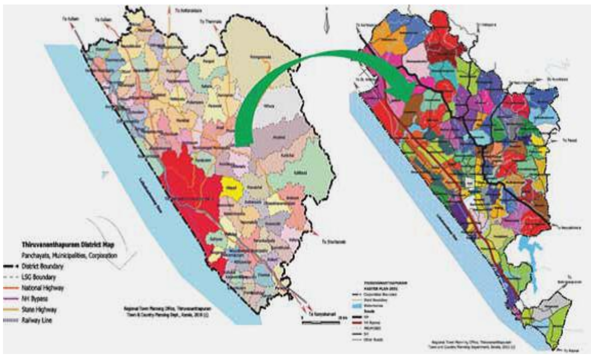

Fig.1 Study area

III. METHODOLOGY

The general methodology used for the engineering and geologic evaluation of the aggregates from the different quarries in the study area is presented by a flowchart shown in Figure 2. The methodology involves collection of aggregates from different quarries in the study area and its testing. Field visits are carried out to the identified quarries in the study area. The geographical locations of the quarries are confirmed using GPS. Tests for determining the engineering properties and geologic properties were done.

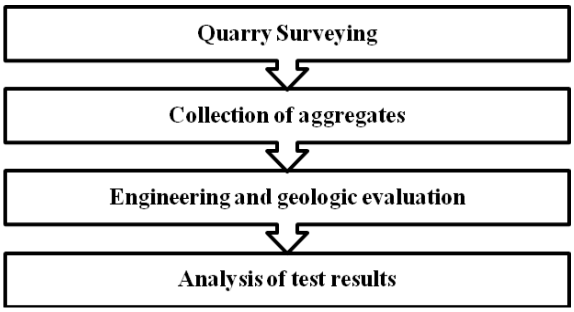

Fig. 2. Flowchart showing methodology

A. Quarry Surveying

Aggregate samples were collected from quarries and crusher units in the study area. Field data collection is essential for mapping of quarries in GIS environment. It also include the collection of data regarding the current status of functioning of the quarries. GPS locations of various station points were also identified. Data collection on various quarries was carried out based on a questionnaire. Fresh rock samples were collected for relevant studies. Mainly two types of rocks were selected for study: Garnetiferous Biotite Gneiss (GBG) and Charnockite. GBG, a coarse to medium grained Leucocratic rock with well-developed foliation and banding, was the most predominant rock type of the area. The light coloured bands in GBG is feldspar and quartz, while the dark bands consist of biotite or garnet.

Fig 3 Garnetiferous Biotite Gneiss

Charnockite was the second most abundant rock type in the study area. It is a felsic, melanocratic alkali granulite rock, typically clear but dark in color. The rock itself has a greasy appearance. It was medium to coarse grained, equigranular and well jointed.

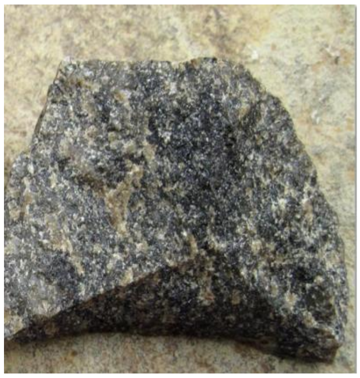

Fig. 4. Charnockite

B. Engineering and Geologic Evaluation

Aggregate samples of Charnockite and Garnetiferous biotite gneiss rock types were collected from the respective quarries in Trivandrum. The tests for engineering evaluation of the aggregates are conducted in accordance with the guidelines provided in IS codes.

TABLE I ROCK PROPERTIES AND TEST TYPE

Property	**Test Type**
Physical Characteristics	
Density	Laboratory Method (IS 2386 Part 4 - 1963)

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Specific Gravity	Laboratory Method (IS 2386 Part 4 - 1963)
Water Absorption	Laboratory Method (IS 2386 Part 4 - 1963)
Shape of Aggregate	Shape Test (IS 2386 Part 1 - 1963)
Strength Characteristics	
Toughness	Aggregate Impact Test (IS 2386 Part 4 - 1963)
Crushing Strength	Aggregate Crushing Test (IS 2386 Part 4 - 1963)
Hardness	Los Angeles Abrasion Test (IS 2386 Part 4 - 1963)

IV. RESULTS AND DISCUSSIONS

A. Study of Physical Characteristics

Specific Gravity

Specific gravity is the ratio of the density of a substance to the density (mass of the same unit volume) of a reference substance. The results of the experiment conducted as per IS 2386 Part 4 - 1963 is tabulated in table II. Specific gravity of aggregate ranging from 2.6 to 3 is generally considered desirable for the road construction applications.

TABLE II SPECIFIC GRAVITY OF ROCKS TESTED

Rocktype	**Average Specific Gravity**
Charnockite	2.8
GBG	2.69

Water Absorption

Water absorption value defines the capacity of a stone to absorb moisture when immersed in water. The results of the experiment are shown in the table. Generally a value less than 0.6% is considered desirable for surface course.

TABLE III WATER ABSORPTION OF ROCKS TESTED

Rocktype	**Average Water Absorption**
Charnockite	0.17%
GBG	0.24%

Shape

The particle shape of aggregate mass is determined by the percentage of flaky and elongated particles contained in it and by its angularity. The combined flakiness and elongation indices for aggregates must not be greater than 30% as per MoRTH specifications. The angularity number of aggregates generally ranges from 0 for rounded gravel to about 11 for freshly crushed angular aggregates.

TABLE IV SHAPE TEST RESULTS OF ROCKS TESTED

Rocktype	**Elongation Index**	**Flakiness Index**	**Angularity Number**
Charnockite	13%	11%	8
GBG	12%	14%	7

B. Study of Strength Characteristics

Toughness

The property of a material to resist impact is known as toughness. Aggregate impact test is the test designed to evaluate the resistance of the aggregates to fracture under repeated impact. As per IRC the maximum Permissible aggregate impact value for surface course is 30%.

TABLE V TOUGHNESS OF ROCKS TESTED

Rocktype	**Average Aggregate Impact Value**
Charnockite	27.15%
GBG	29.03%

Crushing strength

The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied compressive load. As per IRC the maximum Permissible aggregate crushing value for surface course is 30%.

TABLE VI CRUSHING STRENGTH OF ROCKS TESTED

Rocktype	**Average Aggregate Crushing Value**
Charnockite	27.4%
GBG	29.87%

Hardness

It defines the resistance of a stone to rubbing and grinding action under the wheel of the traffic as also due to mutual attrition. If the rock is not sufficiently resistant to this type of action, it may wear out at a rapid rate causing losses. According to IRC specifications the maximum permissible value of abrasion for surface course is 30%.

TABLE VII HARDNESS OF ROCKS TESTED

Rocktype	**Average Aggregate Abrasion Value**
Charnockite	29.16%
GBG	29.56%

C. Study of Geologic Characteristics

Charnockite

Charnockite is a felsic, melanocratic alkalic granulite rock. The charnockites in the study area were dark (greenish grey to bluish black) coloured, medium to coarse grained and mostly equigranular. It is a hypersthenes bearing rock

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exhibiting granulitic interlocking texture [4]. Although mostly it is massive, at places, it shows gneissosity. The rock is mainly composed of feldspar, quartz, biotite and hypersthene. Dark colour is due to the presence of orthopyroxene and cordierite.

Garnetiferous Biotite Gneiss

It is a well foliated medium to coarse grained gneissic rock. It is inequigranular and shows porphyroblastic texture. It has well developed interlocking texture. Most of the grains are subhedral to anhedral. It is mainly made up of quartz, feldspar, biotite and garnet. The light coloured bands are made up of feldspars and quartz while the dark bands consist of biotite or garnet .Feldspars are the most abundant minerals in this rock. The feldspar grains are generally larger than the other grains. The feldspars are followed by quartz, garnet and biotite in abundance.

E. Statistical analysis of test results

The test results were statistically analyzed and the significant correlations were drawn between different physical and strength properties. These relationships are especially useful in cases where one property could be measure easily while it is difficult to find the other one. This usually happens in field conditions. These relationships provide a quick and easy method to estimate the parameters which are otherwise difficult to determine.

Aggregate impact value Vs density

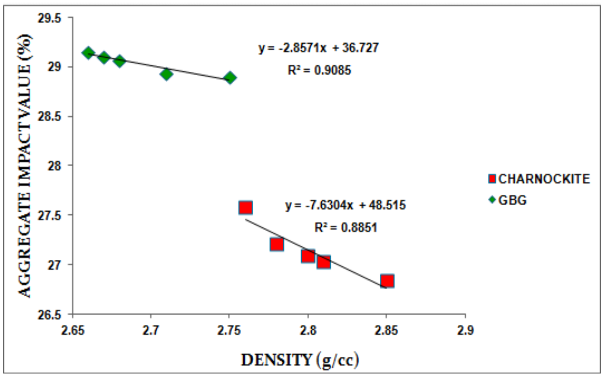

Fig. 5. Aggregate impact value Vs density

Aggregate Crushing Value Vs Density

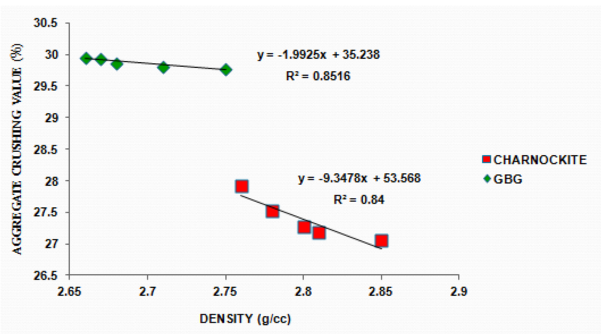

Fig. 6. Aggregate crushing value Vs density

Aggregate Abrasion Value Vs Density

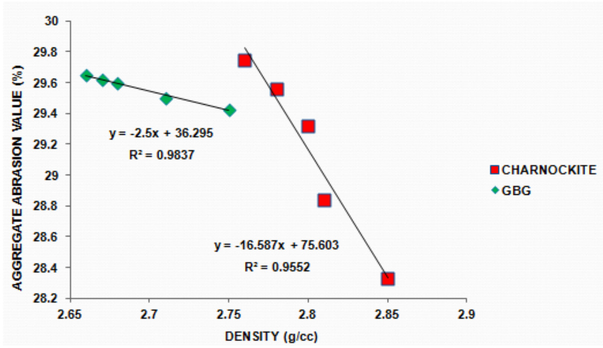

Fig. 7. Aggregate abrasion value Vs density

Water Absorption Vs Density

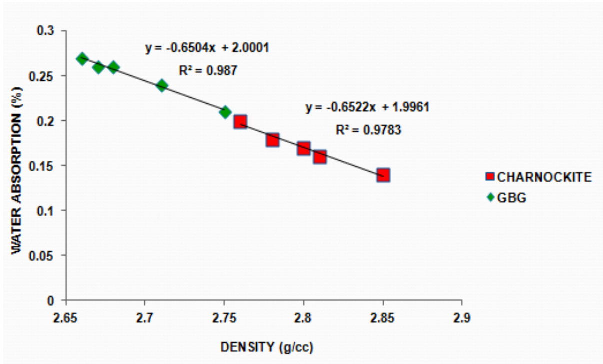

Fig. 8. Water absorption Vs density

F. Discussions

Average density of Charnockite was greater than that of GBG. The density of Charnockite was as high as 2.85g/cc which can be attributed to its medium grained mineral composition.

The specific gravity of the rocks varied from 2.66 to 2.85.According to IS 2386 - 1963 specific gravity of rocks for construction purpose shall not be less than 2.6. Hence the studied rocks are of good quality and can be used for road construction purposes.

The water absorption of the rocks implies their porosity. The water absorption of Charnockite rock was as low as 0.17%. This indicates that the porosity of this rock would be very low and hence better strength properties. According to IS 2386 - 1963 water absorption of the rocks shall not be more than 0.6%. Hence the study area rocks prove to be of desirable quality. Since porosity is very low and water absorption is within limits, the study area rocks can be considered to be sound, and can be used for construction even in consistently water logged areas.

The crushing strength, impact value and abrasion resistance obtained was highest for Charnockite, followed by GBG. Thus out of the studied rocks, Charnockite is most suitable for use in road construction applications.

The soundness values obtained indicates that these are highly durable rocks according to IS 2386 part 5- 1963. Hence these rocks can safely be used for road construction purposes.

As density increases, water absorption decreases linearly. Hence there exist as linear inverse relation between density and water absorption of study area rocks. Rocks with lesser water absorption will have lesser porosity. The particles are more tightly packed with less pore spaces in between and hence the increased densities.

As density increases, toughness, hardness and crushing strength increases. A rock with higher density indicates more solid composition and greater strength.

V. CONCLUSION

On the basis of engineering and geologic evaluation of aggregates from different quarries in the study area, the following provisional conclusions can be drawn.

The area forms a part of Precambrian Crystalline rocks of Peninsular India. The area is composed of Precambrian crystalline rocks and their weathered products. Garnet-Biotite Gneiss, Charnockite, Khondalite are the dominant rock types. Locally, these rock types show considerable compositional variation. Feldspar, quartz, garnet, biotite, cordierite, hypersthene, sillimanite were the minerals found in abundance in the rocks in the study area.

The physical characteristics such as density, specific gravity, water absorption etc. of the study area rocks were investigated and Charnockite rock emerged out as the best rock with favourable properties for road construction purpose. Charnockite has the greatest density and specific gravity and least water absorption. Hence with these properties, it can be reliably used for construction purposes.

To test the suitability of the rocks for use in road work applications, the important properties tested include toughness, hardness, crushing strength and durability. Once again Charnockite led the Garnetiferous Biotite gneiss by considerable margin. Results of this work will be useful in selecting the rock types to quarry for the production of aggregates for optimum use in sustainable road construction.

VI. SCOPE OF FUTURE WORK

For more detailed understanding of the properties of the study area rocks, following work is suggested.

1) A detailed topographic survey of each rock outcrop under exploitation as a quarry including the depth survey should be conducted to determine the exact quantity of usable stone available in each quarry. This should be done before commencement of quarrying operations.

2) The rocks from more quarries in the area may be collected and tested for their properties. The results and discussions are useful for the stone producers as well as clients to know more about technical parameters of rocks used for architectural and civil engineering design.

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