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GEOLOGICAL AND GEOTECHNICAL ASSESSMENT OF AGGREGATES USED IN NAGAR PARKER DISTRICT THARPARKAR SINDH PAKISTAN

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Abstract: This study aims to determine the geology of granite and evaluate the engineering properties of the samples to make recommendations for the construction industry. The study area is situated in the Nagar Parker complex in Pakistan, which is located in the extreme south-east of the Thar District and the desert of the Sindh Province, near the Run of Kutch (24° 15′–35 30′ N, 70° 40′–58 07′ E), and it covers ca. 500–1,000 km2. In this region, several Quaternary deposits, subordinate and dispersed Jurassic–Tertiary sandstones and clays are overlying the Nagar Igneous Complex basement. According to international standards, there are various possible aggregate sources. However, only a few of them have been reviewed for suitability reasons. Six quarries in Nagar Parker, Pakistan, were selected for evaluation as coarse aggregate in concrete construction and civil engineering works in this research. Although the aggregates from the six quarries are specified and already widely used in the Sindh Province, there is a lack of studies on their geological properties. The results of the presented research revealed that samples from Dhedvero, Karai, Nagarparkar, Mokrio, Dinsi and Wadlai meet all of the international standard requirements for aggregates. Geotechnical, petrographic and geochemistry laboratory tests were conducted in this research and included bulk density, water absorption, specific gravity test, index of flakiness and elongation, soundness aggregate test, crushing value aggregate, impact value aggregate and abrasion value of Los Angeles. Furthermore, chemical alkali-silica reaction potential test and petrographic examination were tested. As a result, we evaluated the properties of granite, which is a crystalline igneous rock with a visibly crystalline structure and texture, made up of feldspar, i.e., potash feldspar and oligoclase. The evaluated minerals are compatible with the standards of civil engineering works and can be used as a concrete aggregate. The evaluated three types of minerals included Dhedvero simple intrusion, Nagar pink granite and grey granite.

Key words: geotechnical engineering, granite, aggregate, construction, Nagar Parker

1. INTRODUCTION

To Natural building aggregate is one of the most available and commonly used common resources. The majority of roads, bridges, dams, houses and other infrastructure projects are made up of construction aggregate, crushed and sized rock material used in concrete and asphalt. Construction aggregate accounted for >90% of asphalt paving and 80% of concrete. The rest is made up of a binder like asphalt or cement. Crushed stone accounts for about 52% of all building aggregate, with sand and gravel accounting for the remaining 48% [1]. There are many important factors to be considered when deciding if a rock is suitable for use as aggregates in road construction. The aggregate used in the road's surface course (running surface) must be resistant to the polishing action from vehicle tyres, or the road will become slick, particularly when wet. Aggregates used in construction must be durable.

On the other hand, concrete is a construction substance made from coarse cement paste and fine aggregates. Gravel, sand and crushed stone aggregates are examples of coarse to medium-grained particulate material referred to as 'construction aggregate' or 'aggregate'. Aggregates may be either natural or synthetic, depending on their origin, ACI, E1 [2]. Aggregates are the most quarried materials on the planet, and they are used to add strength to composite materials. Besides that, since aggregates make up more than three-quarters of concrete volume—their physic-mechanical chemical—they have bulk volume and reduce concrete cost. The consistency of the finished product is directly influenced by mineral properties [3]. Destructive manifestations, such as alkali-silica/alkali carbonate reactions/physical effects, may occur if aggregate properties are not up to standard, compromising concrete strength and, as a result, lowering construction quality [4].

Aggregates are valuable raw materials used in various industries, with the cement and building industries being the primary consumers. Physical, mechanical, chemical and mineralogical properties of regional or local aggregate resources must all be considered in a strategic assessment. It is the most common source of coarse aggregate in the construction industry. This rock can be found in large quantities in Pakistan. Pakistan has investigated their suitability for use in various industries, including construction [5–7]. Previous studies [8] examined the engineering characteristics of 35 quarries in the Khyber Pakhtunkhwa (KPK) area of Nowshera. The study identifies locally available aggregates in Nowshera, reducing the reliance on the Margalla crush, widely used due to its high quality and suitability for structure [9, 20]. Aggregates from the Allai region were investigated for use in the restoration and renovation of buildings damaged by the October 2005 earthquake [11]. Earlier studies [12] investigated the effects of freezing and thawing on the hardness of coarse aggregate concrete. Little analysis has been done so far to determine the quality of the resources because the aggregate material is already being extracted in the study area. The classification of aggregate is significant, particularly in the construction of megastructures, since the aggregate material determines the quality of concrete [13–14].

At the confluence of the Thar Desert and Rann of Kutch, Pakistan's Nagar Parkar area occupies about 500 km2. A recently constructed metalled road connects it to Mithi and Badin; the Rann and Indian Territories surround it on three sides. This area is characterised by granitic rock mounds and bold hills in an otherwise levelled landscape of sandy, salty and salty plains, except for the Thar Desert, which is mostly covered by dunes. Karunjhar hill, a prominent desert geomorphic landmark in southeastern Pakistan, rises to 356 m a.s.l. At Karai, Dhedvero and the central part of the district, coarse-grained gabbro dykes and medium- to fine-grained dolerites cut through igneous and metamorphic rocks [15]. Several authors have provided detailed information about geology, mineral formations, petrology and the complex's geochemistry [16–20]. However, we believe that more research into the engineering properties of Dhedvero, Karai, Nagarparkar, Mokrio, Dinsi and Wadlai is required.

1.1. Geological setup

The Nagar Parker area is located in the extreme southeast region of Pakistan, on the border with India (Fig. 1).

Fig. 1. A simplified regional map showing the tectonic configuration and geographical position of Nagar Parker in the Indian shield [20, 37–38]

It is considered the western continuation of the Precambrian Indian shield [20–23]. Existing works [16] presented a geological map of the district, noting Quaternary deposits, subordinate Jurassic-Tertiary sandstone, clay and the overlying basement, and classifying the region as the Dhedvero simple intrusions, the Nagar Parker pink granite and the Karunjhar grey granite (Fig. 3). Small exposures of schists, paragneisses, migmatites and quartzites can be found to the southeast of the Dhedvero and west of Berana, especially near Walo jo Wandio (Fig. 2) and Moti jo Wandio (not shown on the map). At Dhedvero (24°24'27" N, 70°57'14" E), a 75-m-long and 10-m-wide quartzite body was discovered as xenoblock within coarse-grained pink granite.

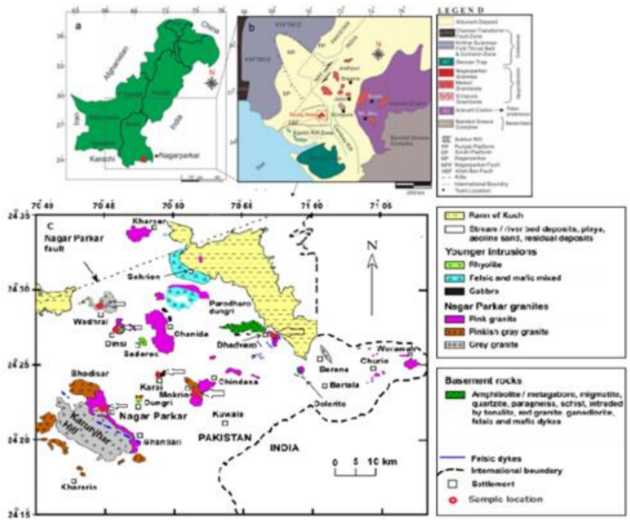

Fig. 2. Regional geological map and geological map of NPIC area, location of samples in the study area (a) the map of Pakistan and location of the study area (b) a simplified regional geological map, showing the tectonic configuration and geographical position of the Nagar Parker area of the Indian shield (modified after the literature [37, 38]) (c) geological map of Nagar Parker, Sindh province of Pakistan [17, 18, 20, 39]

Fig. 3. (a) Dolerite intruding amphibolites at Dhedvero, (b) Dolerite intruding gabbro dyke at Karai, (c) Dolerite intruding gray granite at Nagarparker and (d) Dolerite intruding pink granite at Mokrio [20]

The paragneisses have an N50°W striking angle and a 55° SW dip. Pink granites, mafic and acidic dykes, and amphibolites are intruded by these metasedimentary rock assemblages. Shearing and deformation have occurred in metamorphic rocks, intruded granites, and mafic dykes in various forms. Existing studies [20] classified the Nagar Parker granites into five rock units based on

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field observations and mineral and geochemical compositions: pink, reddish pink, pinkish grey, grey and greyish white granites. Pink granites have minor differences in mineralogy and geochemistry, but they are distinct from grey and greyish white granites [20].

2. METHODOLOGY

2.1. Field work

This research was limited to the aggregates collected from quarries in District Tharparkar: Dhedvero, Karai, Nagarparkar, Mokrio, Dinsi and Wadlai. We performed the examination and evaluation of the coarse aggregate source material which was performed in the study area. Fig. 2 demonstrates the locations of the quarries, which were sampled for the comparison of the minerals.

2.2. Sampling

The device ASTM D-75 was used to collect representative samples from the quarries when necessary [24]. The conveyor belts and flowing barrels were used as stockpiles to achieve the minimum mass recommended by ASTM D-75 in equal increments. The available quarries for this research study are described in the table below along with their selection status.

The samples were then transported to the following laboratories for processing and examination under the ASTM and BS standards: We performed the geotechnical experiments in the Mehran University of Engineering and Technology Jamshoro's Geotechnical and Concrete Laboratory, as well as the Center for Pure and Applied Geology Jamshoro's Petrographic and Geochemistry Laboratory. The following tests were performed: bulk density, water absorption and specific gravity test, index of flakiness and elongation, soundness aggregate test, crushing value aggregate, impact value aggregate and abrasion value of Los Angeles, and furthermore, chemical alkali-silica reaction potential test and petrographic examination were conducted. In the end, the concrete cylinders were observed by compressive strength test.

3. RESULTS AND DISCUSSIONS

3.1. Bulk density

According to literature [25, 26], all of the examined specimens are standard weight aggregates, with bulk densities ranging from 80 pcf to 1,130 pcf (1,130–1,920 kg/m3).

3.2. Specific gravity and water absorption

The aggregates and specific gravity are measured under various moisture conditions: (a) when the water has been poured through all of the aggregate's apertures, the surface still remains dry. This is referred to as a surface dry saturated state SSD. (b) The aggregate is seen to be air dry (AD) when the aperture water is removed by drying it in the air, and bone dry or oven dry (OD) when all the moisture is removed by drying the aggregate in an oven.

The test was conceded in compliance with existing standards [27]. The standard weight aggregates have a relative bulk gravity of 2.4–2.7 (ASTM C 125-03), so the specimens from all quarries are standard weight aggregates. The quarry aggregates have a water absorption value of <2%, which is suitable for construction purposes.

3.3. Flakiness index (FI) and elongation index (EI)

The coarse aggregate's regular geometric texture is essential because they disturb compaction, workability and stress resistance. The workability of concrete and its bonding properties are improved using smooth and rounded aggregates [28]. The workability of the rough, flaky, angular or elongated aggregate, on the other hand, is reduced. This test was conducted following the existing methodology [29], by mass approach. The FI and EI of samples from most quarries are within the acceptable limits of international standards (Tab. 1).

3.4. Soundness

The aggregates refer to their capability to withstand possible weather circumstances, including freeze and thaw cycles, as well as wetting and drying cycles. Temperature changes cause volume expansion, which compromises the resilience of the concrete. This test was conducted according to the existing methodology [30], and all of the aggregate samples were considered sound because their values were within the ASTM acceptable range (Tab. 1).

3.5. Aggregate crushing value

This test was carried out following the standard BS 812: Part 110 [31]. According to the IS: 2,386 requirements, the following are the acceptable limits:
– Concrete Works = 45%
– Pavement wearing surfaces = 30%

We found the aggregate crushing values for specimens from Dhedvero, Karai, Nagarparkar, Mokrio, Dinsi and Wadlai to be <30%, indicating that they can be used on wear surfaces and in other concrete works. Different samples, on the other hand, can be safely used for both concrete and pavement (see Fig. 4 and Tab. 1).

3.6. Aggregate impact value (AIV)

The studied area as Dhedvero, Karai, and Nagarparkar aggregates are appropriate for heavy-duty concrete floorings or rigid asphalts, according to the guidelines outlined in BS 882 [32]. They can also be used in standard concrete projects (see Tab. 1).

3.7. Loss angeles abrasion value

This Loss Angeles test was carried out according to the standard ASTM C131. For the use in concrete, the appropriate range of abrasion is up to 50% (ASTM C-131 and AASHTO T-96) [33], but the specified limits may differ, depending on the type of use (Tab. 1).

Tab. 1. Summary of the test results

Sr. No.	Quarries	Water Absorption (%)	FI (%)	EI (%)	Soundness (%)	ACV (%)	AIV (%)	LAA (%)	Petrography	ASR	Compressive strength (psi)
01	Dhedvero	0.4	25.8	18.2	2.3	25.1	21.8	16.1	Innocuous	Deleterious	4,809
02	Karai	0.5	22.4	15	4.1	29.4	23.4	17.7	Deleterious	Innocuous	4,910
03	Nagar parkar	0.43	16.2	13.4	1.3	18.3	21.3	15.8	Innocuous	Deleterious	5,128
04	Mokrio	0.46	17.1	32.1	2.1	27.2	24.7	15.9	Deleterious	Deleterious	4,712
05	Dinsi	0.54	14.9	14.6	5.7	22.6	25	18.3	Deleterious	Innocuous	4,739
06	Wadlai	0.64	14.8	14	2.3	21.4	25.9	18.1	Innocuous	Deleterious	4,612

ACV, aggregate compression value; AIV, aggregate impact value; ASR, alkai silica reactivity; EI, elongation index; FI, flakiness index; LAA, Loss Angeles abrasion

Fig. 4. Study area samples and varieties used in the construction

3.8. Compressive strength

The compressive strength of the aggregates varies from 12,000 psi to 42,000 psi, while tensile strength is 400–2,400 psi [8]. All of the concrete cylinder samples have identical compressive strength values (Tab. 1). Before being tested for strength, the cylinders were cast according to the requirements and cured for 7 days and 28 days. The ratio of the cylinder casting was 1:2:4, and the water/cement ratio was 0.49.

The results can be found in the remaining information in Tab. 1. Although mortar crushed the majority of the cylinders, a few aggregate particles were found split.

3.9. Alkali silica

A chemical reaction between alkalis in the cement (sodium oxide or potassium) and certain siliceous minerals in the aggregate occurs under certain moisture conditions, resulting in the formation of an alkali-silica gel, which causes concrete expansion/swelling and cracking. We used the ASTM C-289 [34], which is the method to determine alkali-silica reactivity. The aggregates from the respite of the quarries were initiated to be stable.

3.10. Petrographic examination

The existing standard ASTM C 295 [35] specifies a petrographic test. The petrography of the samples revealed that Dhedvero and Nagar Parker samples contain harmful materials. Tab. 1 summarizes the petrographic results of all of the test samples.

There are a few coarse-grained gabbro dykes among the medium- to fine-grained dolerites. Biotite is a mineral that surrounds olivine and clinopyroxene grains in minor quantities (Fig. 5a). Clinopyroxene is found as an oikocryst containing plagioclase in sample 1 (Fig. 5b). Dolerites with a medium to fine grain are found all over the world. The dolerites at Karai are about 25 m wide and 52 m long, with amphibolites and gabbros intruding in the N40° W and N30° E directions sample 2 (Figs. 3a,b). Plagioclase, titaniferous augite, hornblende, biotite and titanite are all contained in these dolerites. Accessories include apatite and zircon. The opaques are magnetite, hematite, titanomagnetite, ilmenite, pyrite and chalcopyrite, and dolerites with medium to fine grain, such as brown, pink and greyish-white granites dating back from 1,100 Ma to 750 Ma (Figs. 3c,d). Pink granite at Nagar Parker, Mokrio, Kharsar, and Wadali, and amphibolite and meta-sedimentary rocks at Dhedvero are situated [20].

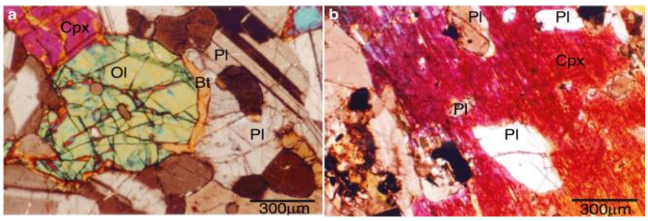

Fig. 5. (a) Photomicrograph of gabbro dyke (sample 1) illustrating olivine, clinopyroxene, and plagioclase. Olivine contains plagioclase as inclusion. Biotite is developed rimming the olivine and clinopyroxene grains. All photomicrographs are taken in crossed polars. (b) Photomicrograph of gabbro dyke (sample 2) showing clinopyroxene oikocryst containing plagioclase

Plagioclase, hornblende and augite are the main minerals in dolerites. They range from subophitic to ophitic in thin sections. Plagioclase, on the one hand, is transformed into sericite, calcite and epidote in part. On the other hand, hornblende is transformed into biotite and chlorite in part. Some of the dolerites that have intruded through the deformed pink granites have been deformed (Fig. 6a). Quartz grains appear as interstitial masses and megacrysts in one of the dyke samples, sample 3. Stresses have fractured the quartz megacryst in sample 3 (Fig. 6b). At the Nagar Parker [36] site, this dyke intrudes 750-Ma reddish-pink granite.

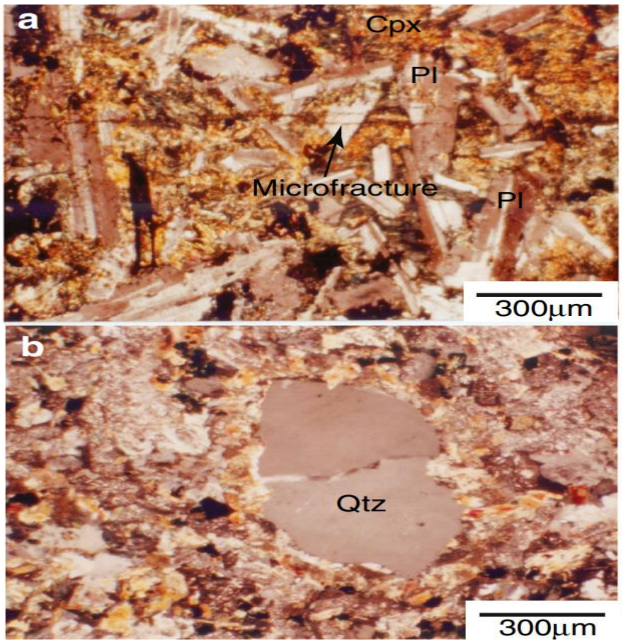

Fig. 6. (a) Photomicrograph of dolerite showing deformation as depicted by microfracture in the rock, the bulk of the rock comprises plagioclase, clinopyroxene, hornblende, biotite and opaques. (b) Photomicrograph of dolerite (sample 3) depicting deformed quartz phenocryst in altered ground mass

The current study revealed that some localities in the Tharparkar and Nagar Parker districts have a substantial supply of coarse aggregate material which can be used as an important material. The crush from the studied area is of high quality, as demonstrated by numerous tests performed on these samples, which revealed that they follow ASTM or BS standards. Next in quality to Nagar Parker and Karai, this has strong physical and chemical properties making it suitable for aggregate use. The Dhedvero crush, on the other hand, had excellent physical results but failed the chemical examination.

4. CONCLUSIONS

The Pakistani Geological Survey estimates over 297 billion tonnes of granite reserves in the Nagar Parkar region of Sindh, Pakistan, with over 25 different granite types in various colours and varieties. We conducted the study to provide information to prospective investors to plan a complete business plan for the quarry of their selection. Granite is a crystalline igneous rock with a visibly crystalline structure and texture. Granite is made up of feldspar, i.e., mostly potash feldspar and oligoclase, primarily whitish or grey, with a speckled appearance caused by the darker crystals. Granite is generally used for outdoor applications, such as flooring tiles, highway design, lodge and house cladding, and so on. Granite contains a specific gravity ranging from 2.63 to 2.7. It has become a common building stone, with applications including external flooring and facing and internal flooring.

In comparison to marble, it is more robust, more durable, less porous and needs less maintenance. Granite does not need re-polishing after it has been polished and fixed in the desired place, while marble needs polishing at least once every two years because of the rigid compacted granular shape. The low porosity of granite does not absorb water and is thus commonly used in kitchens, bathrooms, research laboratories and other offices. Aggregates are used in all civil projects, such as houses, bridges, dams, canals, highways and railway tracks. Therefore, the construction industry is dependent on the supply of granite worldwide. Nagar Parker granite has all the engineering characteristics for road construction in compliance with existing standards AASHTO, ASTM and BS due to its negligible low porosity and strong crushing strength. Besides, the increased road construction in Thar District's surrounding areas and quality development to supply aggregates to the local market and reduce long-distance transportation costs. To classify the mineralogy grain, we used both petrologic and petrographic methods in the study which include size, shape, fabric and weathering states.

5. RECOMMENDATIONS

Based on the findings of this study, the following recommendations have been made:
- The aggregate deposit is highly recommended for use in all types of concrete and highway construction.
- Nagar Parker aggregates can be used safely on regular roads and concrete projects.
- The aggregates Dedhvero and Karai are more appropriate for the building.
- The Mokrio, Dinsi and Wadlai aggregates performed well in physical tests to be used in everyday construction.
- More studies should be conducted in the adjacent areas of Nagar Parkar and Tharparkar in light of the present study.

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