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EVALUATION OF SHAKI SARWAR AND RAJAN PUR AGGREGATES FOR CONSTRUCTION IN SOUTHERN PUNJAB PROVINCE, PAKISTAN

BY

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ABSTRACT: *Colossal quantity of performance bound and economical aggregate is required for in progress and planned mega projects in southern Punjab. The aggregates from established area along with two new sources were sampled and geotechnically and petrographically evaluated for their suitability as valuable aggregates. Girdu Limestone exposed along Multan-Quetta road, N-70, showed the best results as potential aggregate source for asphalt and cement concrete. It will not only drastically trim down the cost but will enhance performance life of buildings, bridges, barrages and roads.*

Besides this source, aggregates deposited in alluvial fans of ephemeral streams like Kaha/Khalgari, Pitok and Zungi is good quality aggregate for road sub base and base course. However, the presence of quartz wackes imparts this aggregate hydrophilic character that proscribes its use in asphalt and cement concrete.

INTRODUCTION

In southern Punjab, from Khanewal to Sadiqabad many national and provincial mega projects are under executions that require huge quantity of aggregates. The public and private sector is thriving to search out good quality aggregate for such projects to substantially reduce the cost of projects. In order to explore physiochemically durable and economically cheap crushed aggregates this study was taken up in Sulaiman Range.

A variety of aggregates for road construction are available in the Punjab province. Crushed rock aggregate is mainly derived from limestone outcrops of Margalla Pass (e.g. Ahsan et al., 2000), crushed gravel and sand (e.g. Chaudhry et al., 1999) is mined from river deposits and alluvial terraces. Other mineable deposits for aggregates are situated near Attock (Indus gravel and sand), Taraki-Dina quarries near Jhelum and a number of small crushers and gravel pits situated at various locations through out the Punjab province (e.g. Ahsan et al., 2000; Gondal et al., 2004a, 2004b). Besides these sources, Neoproterozoic outcrops of Kirana Hills in Sargodha and Chiniot area are the major quarries of aggregates (Alam, 1987; Alam et al., 1988; Khan and Chaudhry, 1991; Khan, 2004) for road construction, ordinary Portland cement concrete, railway ballast and riprap, etc.

In the southern Punjab (Gondal et al., 2006a, b), Sakhi Sarwar quarries (D. G. Khan) are considered the third longest quarry site where approximately 70 crushers have been installed since long and they are crushing boulders/gravels retrieved from Shaki Sarwar gravel complex. Each crusher is producing 6 to 7 trucks of aggregate per day with average capacity of 750 cft per truck. In order to meet demands of mega projects 10 crushing plants are supplying crushed rock aggregate (about 7500 cft /day) for sub base and base course in highway projects in Muzzafar Garh, D. G. Khan, Layyah, Vehari, Bahawal Pur, Bahawal Nagar, Multan and Rahim Yar Khan districts. Besides mechanical crushing facilities, base course aggregate is also produced by manual stone breaking

process in Sakhi Sarwar area. Another extensive source of aggregates are alluvial fan complex along Sulaiman Range from which coarse and fine aggregate is mined through open pit excavation and transported to construction sites in southern Punjab for sub base and base course aggregates. All these quarry sites are approved sources for Punjab Communication and Works Department for base. However, crushed rock aggregate from Shaki Sarwar is not approved for cement and asphalt concrete.

It is therefore imperative to evaluate the sources whose crush can safely be used in asphalt and cement concrete work. In this context, the present study was carried out to find and evaluate such rocks that meet the following requirements. 1) Extensive source is available for aggregate crushing, 2) show good bitumen adhesion, 3) free from deleterious effects like alkali aggregate reaction in cement concrete through its performance period and 4) located near to end users so that transportation cost and other taxes may be reduced. The rock outcrops along Multan-Quetta road (N-70) district D. G. Khan, Kaha/Khalgari, Pitok and Zungi Nullahs aggregates from Sakhi Sarwar and Girdu of district Rajanpur in Sulaiman Range were sampled for evaluation of their engineering properties.

SAKHI SARWAR AND GIRDU AREAS

Sakhi Sarwar and Girdu areas (lat. 29°50'-29°30' N and long. 70°00' - 70°30' E, in District DG Khan) dominantly comprises gravel terraces and outcrops of various rock types (Iqbal and Shah,1980) that are accessible through recently widened Multan-Quetta road. The Sulaiman Range in this area exhibits NS trending Fort Munro anticline. The outer hills of this range comprises gravel beds, sandstone and shale (Siwaliks) which rise abruptly from plains (372m) to about 1939m at Fort Munro. Immediately in the back, older tertiary formations comprising variegated shale and sandstones with thin layers of limestone (Shah, 1977, Iqbal and Shah, 1980; Malkani, 2004, 2006) are exposed. In Girdu area dark grey, hard and thick bedded limestone with intercalated marl beds is exposed (Shah, 1977; Kazmi and Jan, 1997) along both sides of the highway N-70. It is overlain by thin to massively bedded, off white to brownish quartzose sandstone. At places argillaceous limestone and shale horizons also outcrop (Hunting Survey Corporation, 1961; Malkani, 2004, 2006). The outcrop of limestone with distinct dark gray colour is exposed between 62+500 km and 67+900 km on the N-70 and extends upto village Girdu.

In addition to limestone exposures, numerous terraces occur in alluvial fans that are composed of granular material in the size which ranges from boulders to sand. These gravels and sand is transported by various stream originating from the adjacent rising Sulaiman Range. These clasts comprise off-white to brownish quartzite, hard and tough sandstone with subordinate limestone pieces. The rock fragments are generally rounded. The exposed surface of the fragments indicates effects of desert varnish.

KAHA/KHALGARI, PITOK AND ZUNGI NULLAHS

Pitok, Zungi, Khalgari and Kaha Nullahs are ephemeral streams. In these areas rainfalls are erratic and likely to occur in several brief torrential showers. Locally these torrents are known as Rud Kohi and their discharge produce uncontrolled flood, extensive erosion and loss of property and life in some cases. These torrents transport rock blocks/boulders to sand and clay sized material from hills onto the piedmont to develop gravel fans. The flow of the ephemeral streams gradually dissipated through distributaries on gravel fans/piedmont slopes and develops terraces.

Pitok Nullah Quarry

Pitok Nullah is a potential quarry of the area (lat. 29º 09’ to 29º15’ N; long. 69º 54’ to 70º E). Nullah Pitok drains a large sedimentary area of the Sulaiman Range. Its drainage pattern is structurally controlled and many second order streams join it. The nullah cut across the range at Pitok and deposits its load forming a 1km wide terraced gravel fan. This source is 49 km from Rajanpur inclusive of 27 km Katcha track. The height of these terraces varied between 20ft to 150ft from nullah bed. Presently, Kachhi Canal contractors are using its aggregate but it had never been used by Highway Department due to inaccessibility to the alluvial fan area. The material mainly comprises limestone and sandstone.

Zungi Nullah Quarry

The aggregate source area of Nallah Zungi (lat. 28º54’ to 29º00’ N; long. 69º43’ to 69º55’ E) is situated 33 km from Rojhan Chowk at Indus Highway (N-55). This Nullah traverses through various sedimentary rocks of Dera Bugti hills. In down slope areas, fine sediments are abundant and toward plain area gravelly bed comprising limestone boulders and gravel occurs. This gravelly bed extends many kilometers in length. The width of Nullah was more than 300 meter whereas its terraces are wider.

Khalgari and Kaha Nullahs Quarry

Khalgari and Kaha nullahs (lat. 29º21’ to 29º36 N and long. 69º56’ to 70º04’ E) are the potential quarry area of gravel and sand deposits that is accessible through existing road network. A metalled road traverses through the fan area. The road passes through fan area that starts from Indus Highway at Jampur and after crossing Fazilpur, Lalgarh, Lundi Saiyidan and Shahzadgor, it terminates at Mari in Sulaiman Range. These nullahs originate from severely dissected anticlinal area where olive

green, greenish grey, grey and brownish coloured shales, reddish brown to brown and grey sandstones are exposed. Close to Shahzadgor thick beds of offwhite to creamish coloured limestone about than 300 feet thick is present. It is underlain by dark grey marl and overlies whitish to grey coloured gypsum bed. Khalgari and Nullah Kaha nullahas form a 3 to 4 kilometers wide gravel fan that has been uplifted and dissected. Neotectonis has developed four terraces at different levels. The boulders exposed on the terraces indicate effects of desert varnish.

SAMPLING

In the present study gravel deposits and outcrop samples from Tahli Wala Pull-Girdu area comprising quartzite and limestone samples were taken to assess its suitability for surfacing and asphalt concrete work. However, the crush and pit run gravel deposits of Sakhi Sarwar area have already been approved for use as base course and sub base course material.

In Pitok, Zungi, Khalgari and Kaha Nullahs areas, samples of pit run gravels were collected from nullah beds and gravel fan area. Crush samples were collected from crushing plant located close to Uzman Fort in Mazari area which was operating to produce crush.

ENGINEERING PROPERTIES

A number of factors control behaviour of aggregates in mortar, concrete and unbound and bound pavements, etc (Fookes et al. 1988; Yoon and Tarrer, 1988; Lafrenz, 1997; Wu et al., 1998; Dewar, 1999; Hudson, 1999; Kandhal et al., 2000; Neville, 2000). Over a period of time the researchers have come up with a number of aggregate tests that can help them to anticipate in-service performance of aggregates being used in construction works. It is common practice to use durable and strong aggregate that can resist abrasive wear and disintegration, give an excellent bond with cementing materials, resistant to rapid impacts and sound enough to resist extreme weathering conditions (e.g. Smith and Collis, 2001; Sherard et al., 1984; Ahsan et al., 2000; Neville, 2000; Chaudhry et al., 1999, 2006).

The present study deals with selection of suitable aggregate resources, mainly for roads and highways and partly for cement concrete in southern Punjab. In this context gradation (AASHTO T-27), specific gravity and water absorption (AASHTO T-85), soundness test (AASHTO T-104), Los Angeles abrasion value (AASHTO T-96), modified proctor test (AASHTO T-180), California Bearing Ratio (CBR, AASHTO T-193), plasticity index of fines (AASHTO T-88), and coating and stripping test with 60/70 and 80/100 bitumen (AASHTO T-182) were conducted for the determination of engineering properties of aggregates ensure selection of best quality aggregates for future use.

Following the test procedures the calculated specific gravity (AASHTO T-85) of the test samples ranges from 2.61 to 2.69 with an average of 2.65 whereas the water absorption 0.57% to 1.65% giving a mean of 0.74%. Although there are no specified limits for specific gravity in the standards (e.g. AASHTO T-85-88) however values of specific gravity and water absorption are comparable with the available aggregates of Punjab (e.g. Ahsan et al., 2000; Khan, 2004). The above mentioned specifies a maximum limit of 2% for water absorption aggregates.

Many workers (e.g. Fookes and Collis, 1975; Wu, et al., 1998) suggested for durability evaluation of the material that is an important requirement of rock aggregates. Fookes et al., (1988) considered that the aggregate should be sound enough to resist intense mechanical and chemical weathering conditions (Wu, et al., 1998; Navilli, 2000). In present work, Los Angeles abrasion test and soundness of the aggregate were carried out to compare durability of the materials with the standards. Soundness by using Na_2SO_4 solution indicates an average value of 3.07% with a minimum value of 1.80% and highest value is 3.77%. These values are suggestive that the aggregate is very sound and can perform well under severe conditions. In the standard specifications (AASHTO T-104) permissible limit of degradation of the aggregate is taken as 12% for base course and 10% for ordinary Portland cement concrete. Similarly, Los Angeles abrasion values for these aggregates range from 17.9% to 30.6% with an average value of 22.6%. Specified values for sub base, base course, asphalt and cement concrete are 50%, 40% and 30%. As such the achieved values are within specified limits, but it in case of blends in asphalt and cement concrete the values are much closer to maximum specified limits in the literature (ASTM Designation C-131; Gondal et al., 2004a, 2004b). Therefore, some precautionary measures must be observed in order to use the aggregate in asphalt and cement concrete (Smith and Collis, 2001; Navilli, 2000).

Modified Proctor compaction test is a procedure to calculate the maximum dry density and moisture content of soils and aggregates (AASHTO T-180). All the samples were subjected to modified Proctor procedure to evaluate the maximum dry density and optimum moisture content on the 65% of coarse and 35% fine. The value of maximum dry density ranged from 143.7pcf to 144.9pcf with an average of 143.95pcf. Where as the optimum moisture content varied from 5.2% to 5.4% and showing average value of 5.3%.

California Bearing Ratio (CBR) is an extensively used test to assess strength of the material under load. CBR test in this study was carried out at 100% compaction level under soaked conditions (AASHTO T-193). The coarse and fine ratios were combined as they were available in natural deposits. The values range from 84.4% to 99.2% (mean is

94.32) at 100% compaction. Normal requirement for base course is 80% and for sub-base course is 30% at 100% compaction level.

Plasticity index of fines present in the gravels of Pitok Nullah were determined.. Plasticity index is the numerical difference between liquid limit and plastic limits in accordance with AASHTO T-88. Plasticity Index value of these two samples are 5% and 6% whereas the liquid limit of the samples is 24 and 22. According to values given in literature these values are less and should not exceed 25%. The maximum values of liquid limit and plasticity index are 4% for base course 6% for sub base and in case of cement and asphalt concrete, the fines should preferably be non plastic.

The collected samples of crush were evaluated to determine their ability to retain bituminous film (AASHTO T-182) in case of 80/100 and 60/70 immersion in water (16-18 hrs) grade bitumen. Six out of fifteen samples at 25°C qualified the test requirements with bitumen adhesion values (Table 1).

PETROGRAPHIC ANALYSIS (ASTM C-295)

Limestones are generally hydrophobic in nature and show good affinity with bitumen whereas quartzitic sandstone/quartizites are hydrophilic in nature and show poor affinity with bitumen (Smith and Collis, 2001; Bell, 2007). The samples from Girdu Formation, Zungi nullahs and Uzman quarry are hydrophobic in nature therefore they may make good bond with bitumen. Whereas samples from Pitok Quarries 1, 2 and 3, Sakhi Sarwar (Hussain Cotex crusher), off white to white quartzite, Khalgeri Nullah/Kaha Nullah Quarry 7 and 8 are hydrophilic and they are not suitable aggregate sources for asphaltic concrete. In addition to this microscopic analysis of Khalgeri Nullah/Kaha Nullah aggregate indicates that it may not form good bond with bitumen as it contains 57.5% quartz, 35.5 % clay and microcrystalline quartz.

In the presence of certain types of aggregates (e.g. quartzite, greywacke, strained quartz, etc) alkali hydroxides originating from the Portland cement form a gel that induces cracks in concrete thereby deteriorating the civil structures (Gillot, 1969; Hobbs, 1978, 1988; Hudec, 1989; Chaudhry and Zaka, 1998; Chaudhry et al., 2004). Besides modal analysis, for precise assessment of such deleterious constituents present in aggregates, mineralogical composition under the microscope is a pre-requisite to predict the in-service behaviour of aggregates. In this regard, microscopic evaluation of aggregates indicates the presence of 2.5% carbonate and 35.5% clay and microcrystalline quartz in Khah/Khalgeri nullah samples that may induce alkali aggregate reaction. Similarly, some rock fragments in Zungi Nullah also contain microcrystalline quartz and clay.

Petrographic modal analysis of crushed aggregate of Khah/Khalgeri and Zungi nullahs shows the presence of 55% and 1.0% quartzwackes that may cause alkali aggregate reaction when used with high alkali and ordinary Portland cement. However, to predict the alkali aggregate reaction behaviour of aggregates of this area a detailed study is required.

DISCUSSION AND CONCLUSIONS

Dark grey limestone of Girdu Formation exposed along N-70 from Tahli Wala Pull to Girdu revealed low water absorption (0.57% to 1.65%, mean is 0.74%) and is hydrophobic in nature. Other properties (e.g. LAV) indicate that the limestone under study is hard, tough to hammer, durable and its physical properties are comparable with Marglla Hills crush (one of the best aggregate resources in Pakistan). It is an excellent resource for surface treatment, asphalt and cement concrete work.

Girdu Formation is exposed along both the sides of the road (N-70). The Girdu valley is quite wide at number of places that may be suitable for open pit mining and installation of pit face crushers where haulage distance is about 100 to 150 meters. Tahlli Wala Pull is approximately 18 km from Sakhi Sarwar where as Girdu is at 23 km distance and locally it could be a market for the crushed stone. The area in general is barren as it receives scarce precipitation and population of this area has limited economic resources. In case, this quarry is developed as a potential resource for construction material, it will definitely elevate the economic conditions of local populace.

Nullah Khalgeri/Kaha

Khalgeri/Kaha Nullah gravel fan is considerably of large extent and if observed through satellite imagery, it is one of the largest gravel fans of Sulaiman Range. One crushing unit located at the crest of this fan for which large pieces are picked up manually from terraces and transported to crusher located on the road side of the fan. However open pit mining material is transported to the crusher installed for Kachhi Canal at Harand. These crushers crushed predominately quartzite/sand stone material of light brown to reddish brown colour.

Off white to light gray coloured limestone outcrops close to Shazadgore. The test results of the limestone bed indicate that limestone is suitable for use in sub base, base course, asphalt concrete and cement concrete. In addition to this terrace deposits comprising predominantly of sandstone/quartzite are hydrophilic in nature that can be used as sub base and base course material while the same did not qualify for use in asphalt concrete and cement concrete.

Table 1
Physical properties of crushed rock and gravel of Shaki Sarwar and Rajan Pur areas

No.	Description	Specific Gravity	Water Absorption %	Sodium Sulphate Soundness %	Los Angles Abrasion Value%	Max. Lab. Density(pcf) S/Base (max)	Optimum Moisture Content%	CBR Value % 100% compaction	Area coated 60/70 Grade Bitumen Immersion in water (16-18 hrs)	Area coated 80/100 Grade Bitumen Immersion in water (16-18 hrs)
1	Dark grey Girdue limestone	2.67	0.58	3.77	21.9	144.9	5.2	98.7	Above 95%	Above95 %
2	Dark grey Girdue limestone	2.66	0.61	3.59	22.4	144.7	5.3	96.2	Above 95%	Above 95%
3	Dark grey Girdue limestone	2.68	0.57	3.59	22.3	143.7	5.2	96.3	Above 95%	Above95 %
4	Dark grey Girdue limestone	2.67	0.58	3.65	21.8	144.2	5.2	96.4	Above 95%	Above95%
5	Off white to white quartzite	2.66	0.66	3.65	19.2	144.6	5.3	95.3	Below 95%	Below 95%
6	Off white to white quartzite	2.67	0.67	3.44	19.8	144.6	5.4	95.4	Below 95%	Below 95%
7	Sakhi Sarwar (Hussain Cotex crusher)	2.65	0.64	3.68	21.8	144.5	5.4	94.2	Below 95%	Below 95%
8	Pitok Quarry 1	2.69	0.72	2.85	20.9	143.7	5.3	96.2	Much below 95%	Much below 95%
9	Pitok Quarry 2	2.65	0.71	2.93	30.6	144.2	5.2	96.3	Below 95%	Below 95%
10	Pitok Quarry 3	2.61	0.69	3.20	25.1	144.5	5.2	94.8	Much below 95%	Much below 95%
11	Pitok Quarry 4	2.65	0.89	1.80	24.6	143.7	5.3	95.1	Below 95%	Below 95%
12	Uzman Quarry (Nullah Zungi) 5	2.65	0.70	2.56	26.2	144.9	5.3	99.2	Above 95%	Above 95%
13	Uzman Quarry (Nullah Zungi) 6	2.63	0.76	2.44	17.9	144.7	5.4	91.0	Above 95%	Above 95%
14	Khalgeri Nullah/Kaha Nullah Quarry 7	2.65	1.65	2.56	24.2	143.7	5.4	84.4	Much below 95%	Much below 95%
15	Khalgeri Nullah/Kaha Nullah Quarry 8	2.67	0.67	2.36	21.2	144.2	5.3	85.4	Much below 95%	Much below 95%
AVERAGE		2.65	0.74	3.07	22.66	143.95	5.3	94.32		

Nullah Pitok

The material comprises limestone and sandstone. Installation of material separator was observed in Nullah bed. The material of the Nullah qualified only for use as sub base and base. The presence of olive green fines material was suggestive that it should be removed from coarse fraction due to its potential for higher plasticity index value. The coarse fraction is suitable to be used as base and sub base but its use in asphalt concrete and cement concrete may not be suitable.

Nullah Zungi

The test results of these rocks and their hydrophobic characteristics revealed that gravels/boulders bed of Nullah Zungi are suitable for use in sub base, base course, asphalt concrete and cement concrete. If this deposit is developed, it will serve not only Tehsil Rojhan and Kashmore area of Sind. But after construction of Ichha Bunglow high level bridge over the River Indus, it will also meet the requirement of District Rahim Yar Khan and Ghotki area of Sind being the nearest source.

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