GJR Publication
OPEN ACCESS

Global Journal of Research in Engineering & Computer Sciences
ISSN: 2583-2727 (Online)
Volume 02| Issue 06 | Nov.-Dec. | 2022
Journal homepage: https://gjrpublication.com/gjrecs/

Original Research Article

Evaluating the strength of stones for their use as an engineering material – A case study in DG Khan Area of Pakistan

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Submission Date: 17 Dec. 2022 | **Published Date:** 31 Dec. 2022

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Abstract

Stone is a high class naturally available building material which has been used from the early age of civilization for various constructions. It is available in the form of rocks, which is cut to required size, shape and used as building blocks. It is used where permanency of structure is required; it continues to enjoy superiority over bricks and all over rival materials. Flood control infrastructure in Punjab have been under serious threats and suffered with severe erosion, leakages and seepages during floods. Stone is used in pitching of flood bunds for protecting and other hydraulic structures. Keeping in view the importance of the issue, Irrigation Research Institute (IRI) conducted a study for checking the quality and quantity of stone from various quarries by investigating their geotechnical and physical properties for utilization of stones on the flood sector projects. Stone samples were collected from rock by means of quarrying from the three quarries (Kari Khasoor, Draban and PEZU) in Dera Ismaeel Khan Area and shifted to laboratory of IRI. Different laboratory tests including Acid Test, Smith Test, Loss Angeles Abrasion Test, % Absorption, Specific Gravity Test, Slake Durability test, Resistance to Crushing, Soundness Test and Microscopic Petrography by using different ASTM & BS were performed to evaluate the strength and other properties of stones. The results of Acid test indicated that stone samples of all three quarries have not shown any weathering effect when treated with hydrophobic acid. Smith test results indicate no soluble salts are present in all stone samples being taken from three quarries. Los Angeles abrasion test results indicated that loss in stone samples taken from kari khasoor, Draban and PEZU are 23.6, 23.5 and 25.0 % respectively. The loss of weight is within limit. Specific gravity values were observed 2.70, 2.63 and 2.65 respectively while absorption values 0.228, 0.297 and 0.361% respectively indicating within permissible range. Slake durability index are 98.4, 98.2 and 98.7% respectively, indicating very high durability. High value of slake durability index show that stone samples are durable. Crushing values are 32.0, 32.0, and 31.0 respectively. Sulphate soundness test results indicate that loss of stone samples collected from kari khasoor, Draban and PEZU are 0.74, 0.83 and 0.78% respectively. The stone sample is sound against weathering action. It was concluded that stone of these three quarries is of good quality and can be used for various engineering projects.

Keywords: Stone quality, Engineering Materials, Flood, DG Khan, Punjab, Pakistan

1. INTRODUCTION

Stone is a high class naturally available construction material which has been used from early age of civilization. It is available in the form of rocks, which is cut to required size, shape and used as building blocks. It is used where permanency of structure is required; it continues to enjoy superiority over bricks and all over rival materials. It has satisfactorily stood the test of time. When properly selected, it weathers well and does not involve heavy maintenance costs. These qualities have always been deciding factors in its favor for use in permanent engineering works.

Depending upon composition, building stones are classified as Salacious stone (Its base or principal constituent is silica), Argillaceous stone (Its base is clay) and Calcareous stone (Its base is lime or carbonate of calcium).Based on origin of formation stones are classified as sedimentary, igneous and metamorphic stones.

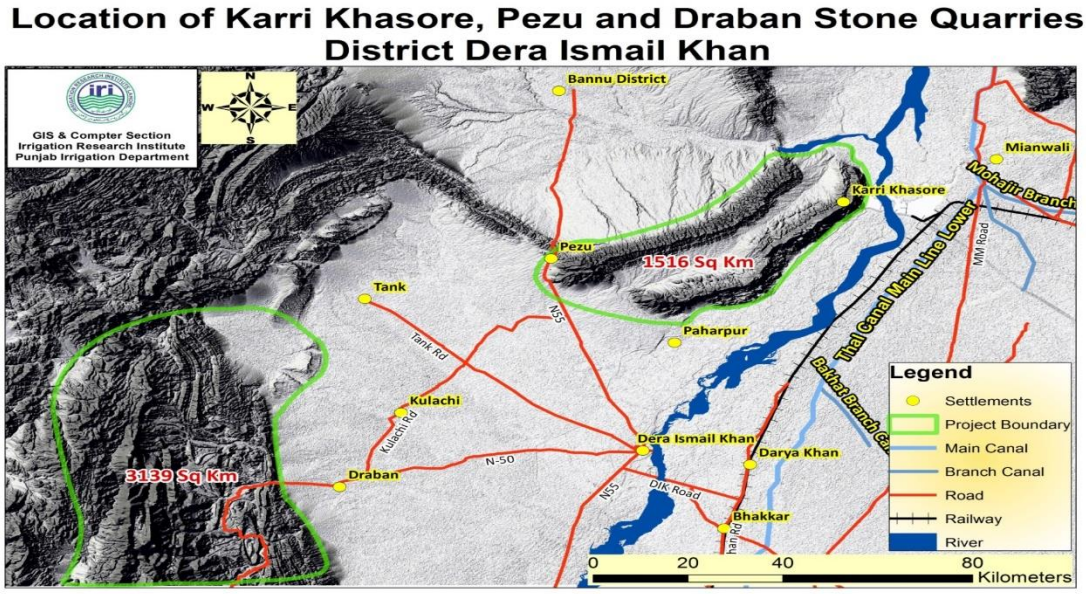
Stone for pitching and masonry should be sound, tough and durable, with no stone less than 200 mm in minimum dimension, except that smaller pieces or spells may be used for filling spaces between the larger stones. Rocks or stones should be of such a shape as to form a stable protection structure of the required section. All stones intended for their use on any particular pitching or masonry job shall receive the prior approval of the Engineer, keeping in view the suitable engineering characteristics.

Stone for riprap should be hard field or quarry stone not susceptible to disintegration or excessive weathering on exposure to the atmosphere or water. It shall be free from soft material such as sand, clay, shale or organic material and shall not contain an excessive amount of elongated stone. The required size of stone will be determined by the "critical mass" specified. At least 50% of the material comprising the riprap shall consist of stones having a mass heavier than the critical mass and not more than 10% by mass of the material shall consist of stone having a mass of less than 10% of the critical mass or more than five times the critical mass.

2.Methodology

2.1 Study Area

Stone samples were obtained from rock by means of quarrying by field formation. The term quarrying is applied to the art of extracting stone of various types for general building and engineering works. The area where the extraction takes place is termed as “quarry”.



2.2Lab Testing

The samples collected in field were analyzed in lab and following tests were performed:

Sr. No.	Name of Tests	Purpose
1	Acid Test	To find out whether stone will withstand the foul atmospheric action in industrial area or not.
2	Smith Test	This test is performed to find out the presence of soluble matter in a sample of stone.
3	% Absorption	This test is performed to determine the % age absorption of water.
4	Specific Gravity Test	This test is performed to measure the strength and quality of the material and to find out the specific gravity of sample.
5	Lose Angeles Abrasion Test	This test is performed for checking hardness and resistance to degradation of stone samples.
6	Soundness Test	This test is performed to study the resistance of coarse and fine aggregates to

		weathering action and to judge the durability of the coarse aggregate
7	Resistance to Crushing	This test is performed for determining the toughness of stone samples.
8	Microscopic Petrography	This test is performed to find out the microscopic properties of stone e.g., average grain size, existence of pores, fissures, veins and shakes, mineral constituents, nature of cementing material, presence of any harmful substance, texture of stones etc.
9	Slake Durability	This test is performed to find out the weathering effect on stone.

2.3 Collection of Stone samples

Stone samples from the three quarries (Kari Khasoor, Draban and PEZU) were collected by concerned Superintending Engineer and shifted to laboratory for performance of tests.

2.4 Acid Test

Purpose of this test is to find out whether stone will withstand the foul atmospheric action in industrial area or not. This test was performed using **BS 812-119:1985**

2.5 Smith's Test

This test was performed to find out the presence of soluble matter in a sample of stone. **Specifications for materials of construction (1964).**

2.6 Los Angeles Abrasion Test

This test was performed using ASTM C 131 and AASHTO T 96-87standards.
This test was performed for checking hardness and resistance to degradation. Stone was crushed and coarse aggregates of different sizes was prepared as prescribed in the ASTM. % Loss in aggregate materials can be calculated. Loss should not exceed 40 % by weight after five hundred revolutions. **Manual of Irrigation Practices (1956).**

Figure2.1: Los Angeles Abrasion Machine

Figure2.2:Spherical balls used in Abrasion Machine

2.7 Absorption of water

This test was performed using ASTM C 127 and AASHTO T 85-91 standards.
This test was performed to determine the % age absorption of water. A good building stone should not absorb water more than 5% of its weight **(Specifications for materials of construction (1964**).

2.8 Specific Gravity

This test was performed using ASTM C 127 and AASHTO T 85-91 standards.
Specific gravity test was performed to measure the strength and quality of the material. Specific gravity is the ratio of weight of aggregate in air to the weight of equal volume of water displaced by saturated surface dry aggregate. Smaller

size aggregates were prepared after crushing of stone samples. Specific gravity shall not be less than 2.60. **Manual of Irrigation Practices (1956).**

2.9 Slake Durability Index

This test was performed using **ASTM D 4644 – 87**. This test method covers the determination of the slake durability index of shales and other weak rocks after two drying and wetting cycles with abrasion. It is a simple test for assessing the influence of weathering on Rock and its disintegration. The slake durability index is used to estimate qualitatively the probable amount of deterioration of weak rocks, over a period of time, after simulated exposure to natural wetting and drying cycles (e.g., estimating the potential severity of air slaking or invert gradation during tunnel construction).

Table2.1 Gamble's Slake Durability Classification (Goodman 1980)

Sr. No.	Group Name	% Retained after one 10 min cycle(dry weight)	% Retained after two 10 min cycle(dry weight)
1	Very high durability	> 99	>98
2	High Durability	98-99	95-98
3	Medium High Durability	95-98	85-95
4	Medium Durability	85-95	60-85
5	Low Durability	60-85	30-60
6	Very Low Durability	< 60	<30

Ref: Swain (2010)

Figure 2.3: Slake Durability Test Apparatus

2.10 Crushing Value Test

This test was performed using IS-2386 part-4 standard. Purpose of aggregate crushing value (ACV) test is to measure the crushing resistance of aggregate under an increasing compressive load. The method is applicable to aggregates passing a 14.0 mm test sieve and retained on a 10.0 mm test sieve.

Table2.2 Aggregate Crushing Test

Desirable Value (Acceptable Range)	ASTM Precision
Near about 30 (As per British Standards)	The aggregate crushing value gives a relative measure of the resistance of an aggregate crushing gradually applied compressive load. With aggregate crushing value 30 or higher, the result may be anomalous and, in such cases, the 10% fines value should be determined instead.
< 45 (As per IS-2386 Part- 4)	The aggregate crushing value for wearing surface shall not exceed 45%.

IS-2386 Part- 4

Figure 2.4: Aggregate Crushing Value Test Apparatus

2.11 Sulphate Soundness Test

This test was performed using ASTM C-88 This test is used to determine the resistance of coarse and fine aggregates to weathering action and to judge the durability of the coarse aggregate. The % loss should not exceed 10% when using sodium sulphate. **Manual of Irrigation Practices (1956).**

Table 2.3: Sulfate soundness Test

Desirable Value (Acceptable Range)	ASTM Precision
6 to 16	For coarse aggregate with weighted average sulfate soundness losses in the ranges of 6 to 16 % for sodium sulfate. (ASTM C-88).
12	ASTM C-33

Fig. 2.5: Soundness Test Apparatus

2.12 Microscopic Examination/Petrography

This test was performed using ASTM C-295. Purpose of this test is to find out the microscopic properties of stone e.g., average grain size, existence of pores, fissures, veins and shakes, mineral constituents, nature of cementing material, presence of any harmful substance, texture of stones etc. The fractured surface of a durable stone should be bright, clean and sharp, with grain well cementing together. Stone likely to decay shows a dull earthy appearance **(Specifications for Materials of Construction 1964)**.

3 Results and Discussion

Results of different tests performed are as under.

3.1 Acid Test

Table 3.1: Results of Acid Test

Sr No	Name Of Quarry	Result
1	Kari khasoor	No Weathering effect
2	Draban quarry	No Weathering effect
3	PEZU quarry	No Weathering effect

3.2 Smith Test

Table 3.2: Results of Smith Test

Sr No	Name Of Quarry	Result
1	Kari khasoor	Clear Solution
2	Draban quarry	Clear Solution
3	PEZU quarry	Clear Solution

3.3 Los Angles Abrasion Test

Table 3.3: Results of Los Angles Abrasion test

Sr No	Name Of Quarry	Loss (%)
1	Kari khasoor	23.6
2	Draban quarry	23.5
3	PEZU quarry	25.4

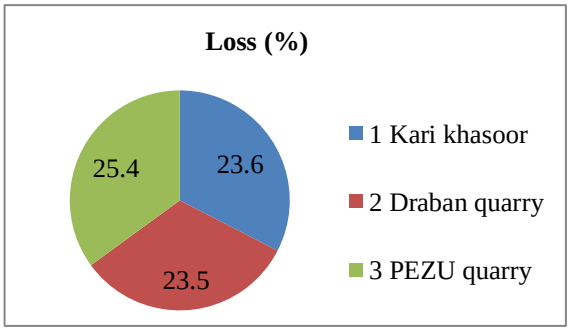


Figure 3.1: Graph showing % loss

3.4 Absorption of water

Table 3.4: Results of Absorption of water

Sr No	Name Of Quarry	Absorption (%)
1	Kari khasoor	0.228
2	Draban quarry	0.297
3	PEZU quarry	0.361

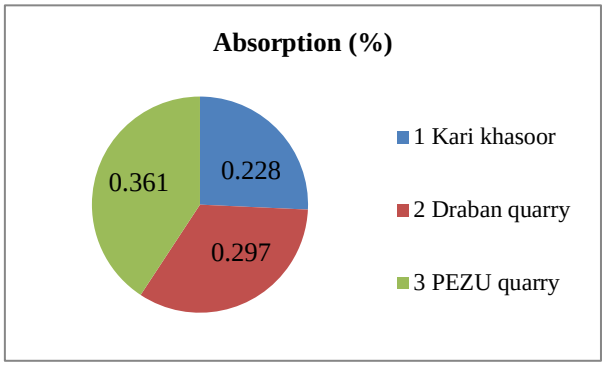


Figure 3.2: Graph showing % Absorption

3.5 Specific Gravity

Table 3.5: Results of Specific gravity test

Sr No	Name Of Quarry	Specific Gravity
1	Kari khasoor	2.70
2	Draban quarry	2.63
3	PEZU quarry	2.65

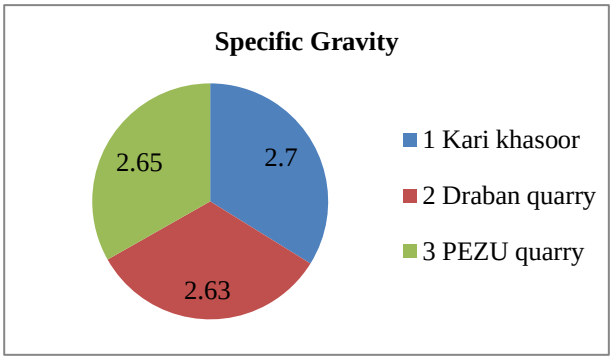


Figure 3.3: Graph showing specific gravity

3.6 Slake Durability Index

Table 3.6: Results of Slake Durability Index Test

Sr No	Name Of Quarry	Slake Durability Index (%)
1	Kari khasoor	98.4
2	Draban quarry	98.0
3	PEZU quarry	98.7

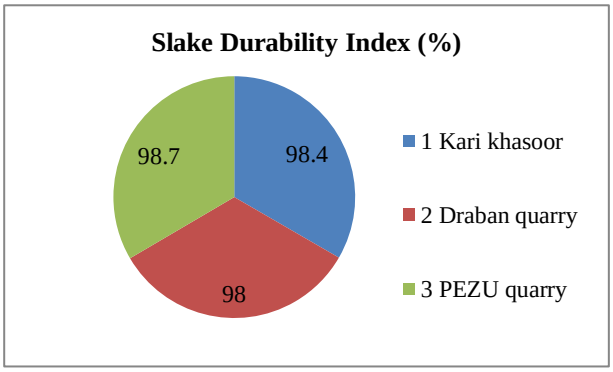


Figure 3.4: Graph showing Slake Durability Index

3.7 Crushing Value of Aggregate

Table 3.7: Results of Crushing Value of Aggregate

Sr No	Name Of Quarry	Crushing Value
1	Kari khasoor	32.0
2	Draban quarry	32.0
3	PEZU quarry	31.0

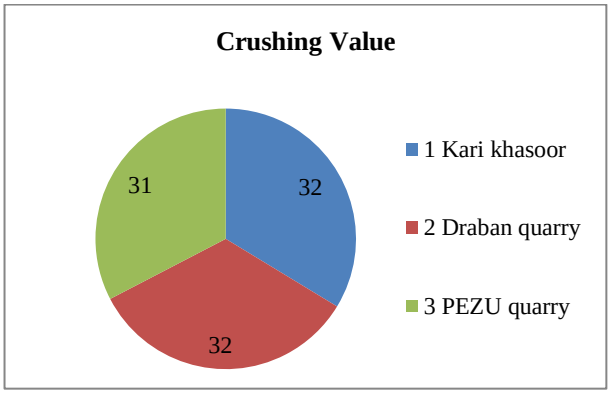


Figure 3.5: Graph showing Crushing Value of Aggregate

3.8 Sulphate Soundness Test

Table 3.8: Results of Sulphate Sodium test samples using Sulphate Sodium test

Sr No	Name Of Quarry	Weighted % Loss
1	Kari khasoor	0.74
2	Draban quarry	0.83
3	PEZU quarry	0.78

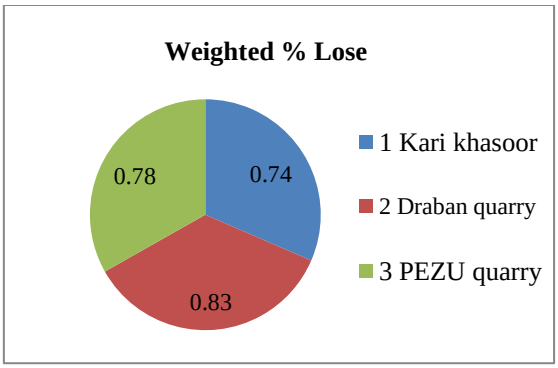


Figure 3.6: Graph showing % loss in

3.9 Microscopic Examination/Petrography of Aggregates (ASTM C-295)

Result	Remarks
The Petrographic studies show that the samples (Kari Khasoor and PEZU Quarry) are non-deleterious. They have neither Alkali Carbonate Reaction (ACR) Potential nor Alkali Silica Reaction (ASR) Potential. Therefore, the samples (Kari Khasoor and PEZU Quarry) may be safely used as aggregates with Ordinary Portland Cement (OPC)/High Alkali cement. Whereas the sample (Draban Quarry) is deleterious. It has Alkali Silica Reaction" (ASR) Potential. Therefore Sample (Draban Quarry) may not be used as an aggregate with ordinary Portland Cement (OPC)/High Alkali Cement.	Stone is to be used on Flood Protection works. Presence of Alkali Silica contents in Draban Quarry Stones does not matter**.**

Table 3.9: Results of Microscopic Petrography

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

i) The results of Acid test indicate that stone samples of all three quarries had not shown any weathering effect when treated with hydrophobic acid.

ii) Smith test results indicate that no soluble salts are present in all stone samples taken from three quarries.

iii) Los Angeles abrasion test results indicate that loss in stone samples taken from kari khasoor, Draban and PEZU are predicted as 23.6, 23.5 and 25.0% respectively. The loss of weight is within permissible limit.
iv) Specific gravity of Kari Khasoor, Draban and PEZU are 2.70, 2.63 and 2.65 while absorption values are 0.228, 0.297 and 0.361% respectively indicating within permissible range. The stone is durable.
v) Slake durability index of kari khasoor, Draban and PEZU are 98.4, 98.2 and 98.7% respectively, indicating very high durability. Greater value of slake durability index shows that given stone sample is durable.
vi) Crushing values of Kari Khasoor, Draban and PEZU are 32.0, 32.0, and 31.0 respectively.
vii) Sulphate soundness test results indicate that loss of stone samples collected from kari khasoor, Draban and PEZU are 0.74, 0.83 and 0.78% respectively. The stone sample is sound against weathering action.

RECOMENDATIONS

1. On the basis of test results, it is recommended that stone of three quarries could be used for flood protection works in Punjab.
2. The quantity of stone is sufficient to fulfill the requirement of the irrigation department for the next twenty years.

Notes:

i) Authors declare no conflict of interest
ii) Views expressed in the paper are the authors' own and do not reflect the point of view of any department or organization.
iii) Cooperation extended by field formation of DG Khan Irrigation Zone in data collection and field survey; and provision of funds by the Punjab Irrigation Department (PID) are acknowledged

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