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Engineering Properties & Comparison of Potential Aggregates Sources Obtained from Erstwhile FATA KP, Pakistan

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Abstract- The paper presents the categorical behaviour of Coarse aggregates obtained from various existing quarries in the former Federally Administered Tribal Area (FATA) of Pakistan for use to make Coarse aggregates concrete. The most easily accessible sites were selected because it meets Peshawar city's demands and FATA. The potentiality was checked through numerous scientific tests such as Bulk Density, Soundness test, Crushing strength values, Los Angeles abrasion test, Gradation technique of Coarse aggregates of these areas. Moreover, the water absorption tests were carried out on the obtained specimen to assess their engineering behaviour as per ASTM specification. Based on the experimental study of this research, sources from the Basai and Bazid Khel revealed that the properties of the coarse aggregate as per the ASTM. The results reveal that aggregates can be suitable for the structural component and may be used in road construction with high traffic loads. According to ASTM specification, Basai and Bazid Khel Coarse aggregates are good alternatives because these construction aggregates are relatively lower in cost because of less distance between Peshawar and Darra Adam Khel. This current source can prove itself as a readily alternative of Coarse aggregates to the construction industry of Pakistan. Kirana hills at Sargodha and Margalla hills are the approved sources of aggregates in Pakistan.

Keywords - Concrete, Coarse aggregate, Physical properties, Mechanical properties, Erstwhile FATA, ASTM.

I. INTRODUCTION

Aggregates are generally taken as natural caulks in the concrete mix. The Coarse aggregate, which is largely used in construction work, dramatically affects the endurance, viability, and economic cost of concrete [1]. Aggregates are used for multidimensional purposes, such as Portland Cement Concrete (PCC), Water Bound Macadam (WBM), railway ballast riprap, Asphalt base pavement, and used as a filler material. The coarse aggregate is the vital phase in concrete formation and is responsible for the adhesiveness of the concrete [2]. Also, Structure aggregates or simply aggregates are the collection of pebbles, sand, crushed stone, etc. This construction aggregate is the primary source used in the making of asphalt products and concrete formation [3].

In other words, the structure aggregate is a refined rock-such as sand, gravel, pebbles, and boulders that are crushed, sieved, cleaned, and is used as adhesive agents to make construction concrete asphalts-based products [4]. The construction industry has great demand for coarse aggregates, the rocks, stones, pebbles, and boulders are mixed up with cement or other cohesive agents as a construction aggregate to make buildings, roads, bridges, plazas, dams, and many other structures involving concrete [5].

The estimated average residential construction material comprises hundred metric tons of aggregate, and approximately one-kilometer road consumed about ten thousand metric tons of aggregate [6]. Coarse aggregates demand, half of the aggregate demand comes from private sector construction companies, and the remaining half from government-owned construction works. It is observed that aggregate demands are on second after a meal [7].

Concrete aggregate means rock-like materials such as sand, boulders, pebble, and gravels, sand recycled that are mixed with cementing agents such as water, cement, bitumen, gypsum, lime, or other cohesive material to make a total quantity of material such as asphalt and Portland concretes [8]. According to American Concrete Institute (ACI) Education EI-07, it is recorded that it consists of seventy-five to eighty-five percent by mass used a huge quantity of aggregate in the construction field [9].

Aggregates naturally found are very less in amount, and most of the quantity is prepared artificially. Natural aggregate is extracted from the open excavation of big rock sources. Then the extracted rocks are grinded through mechanical force to reduce their size to a desirable amount to make it suitable to mix it with other cementing agents [10]. According to United States Geographic Survey (USGS) 2006, the aggregate used as Portland cement concrete is the most used construction material around the world. It is claimed that every year, about seven billion cubic meters of concrete are used. Further, it is estimated that about one cubic meter (1 m3) of concrete is used up for each person in the world [11].

Engineering properties of various quarries located in southern Punjab named Jutana Formation. For road construction, the Sakeasar limestones are considered the most appropriate aggregates. Further, the sakeasar limestone aggregates are used in the manufacturing of ordinary Portland cement concrete. The fine gravel resistance and coarse deposits of Jabbi Warcha and Kathasaghral areas have been evaluated and recommended for construction works [12]. The aggregate has a fundamental role in making the concrete and good production agent to cover the greatest influence on the performance of making fresh concrete [13]. Many researchers have studied various aspects of concrete [24-26]. In addition, many studies focus on the structure health monitoring aspects of structure and early damage detection [27-31]. It is important to study various properties of ingredients of concrete and other structural member to avoid structural collapse.

The use of coarse aggregate in ordinary Portland cement induces an appropriate deterioration in structural element dead load and its cost. Using locally available coarse aggregate improves the structurally application and concrete mix properties to accomplish economic viability [14]. Engineering properties of the Basai area (lat.33° 40' to 33° 05'N; long. 71° 04' to 71° 98'E) of the newly merged district of Khyber, and Eighteen (18) Kilometer away from Peshawar. The Bazid Khel area (lat. 33° 68'to 33° 40N; long. 71° 51' to 71° 60'E) in the erstwhile Region of Kohat district. It is in the south of Peshawar and Forty-three (43) Kilometers away from Peshawar [15].

II. Objectives

The following are the main objectives of this research study.

1. To present the mechanical and physical properties of coarse aggregates selected from the local quarries.
2. To enhance locally inexpensive material for the ongoing construction projects throughout the KP and Pakistan.
3. To reduce the transportation costs by selecting local quarries.
4. Reduction in transportation distance by trucks will ensure environmental sustainability.
5. It is expected that employment opportunities will be increased in the remote areas of KP and especially in erstwhile FATA.

Fig. 1. Bazid Khel Crush Plant in Darra Adam Khel

Fig. 2. Basai Crush Plant in District Khyber

III. Methodology

A comprehensive experimental program was divided into two parts. A sampling of aggregates and then testing them in laboratories. Investigational works were conducted on coarse aggregates in the laboratory of soil mechanics and concrete laboratory of Sarhad University, Peshawar.

A. Sampling of Aggregates from Quarries:

Firstly, the sampling of aggregates is much essential as testing. While choosing samples from the field, the researcher or sampler did utmost care to get a truly representative material. That could surlily express the real nature and state of the material of quarries. Under the size of samples, two samples of gravels were randomly picked from each colour and condition to study the physical and mechanical properties. Each sample was labelled according to its source, location, and property. Coarse aggregate samples from Basai and Bazid Khel were collected according to the standard procedure of ASTM D-75-03 [21]. In this research study, one sample is collected from the stockpile, and three samples are collected from the conveyor belt, as shown in Figures 1 and 2.

B. Physical Characteristics of Coarse Aggregates:

The physical properties of aggregates were measured through ASTM recommended test procedure:

- Specific Gravity.
- Water Absorption.
- Unit weight.
- Sieve Analysis.

It is now well recognized that coarse aggregate's thermal, chemical and physical properties substantially influence the properties and performance of concrete. One of the essential physical properties of coarse aggregate is determining its specific gravity and water absorption, unit weight, and sieve analysis.

IV. MATERIAL AND METHODS

A. Specific Gravity and Water Absorption Test:

The specific gravity and water absorption tests were carried by using the standard procedure of ASTM C-127 [16]. Experiments were conducted to calculate the coarse aggregate's specific gravity and water absorption values. The results of the experiments are shown in the following fig .3 and fig .4, respectively. It is evident from the data of the below figures that the values of specific gravity and water absorption tests of Basai and Bazid Khel quarry coarse aggregate are like that of the approved values of Margalla and Sargodha coarse aggregate.

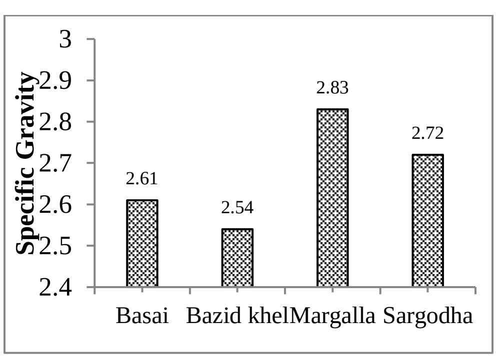

Fig. 3. Specific Gravity of Coarse aggregates

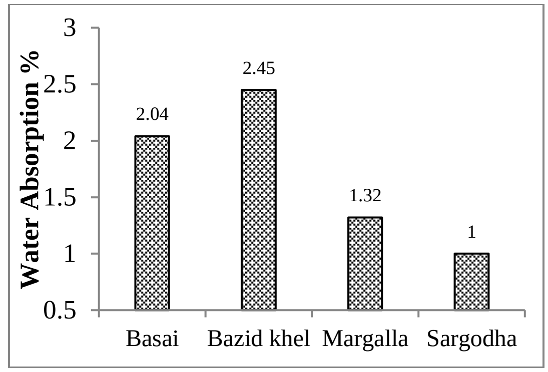

Fig. 4. Water absorption test of Coarse aggregates

B. Unit Weight of Coarse Aggregate:

To determine the unit weight of coarse aggregate under the ASTM C-29, bucket, tempting rod, brush, coarse aggregate, and weight measuring equipment are used. In this method, first, the weight of an empty bucket is determined then the bucket was filled with coarse aggregate with the help of a shovel. After filling, the over-following coarse aggregate was removed through a straightedge. The loose-filled bucket was measured, and the data was recorded. In the next step, the bucket was filled again. After dynamic pressing of the coarse aggregate through a tamping rod, the overflowing coarse aggregate was removed from the bucket. Then the bucket with the coarse aggregate was measured, and the data was recorded. Under the scope of the study, the data has been graphically shown in fig .5 with also shows the lower and upper limits as specified by ASTM C-29 [20]. It is very clear from the unit weight test that the locally available coarse aggregates are equivalent to the amount that is generally used in Pakistan and as per ASTM standard limits.

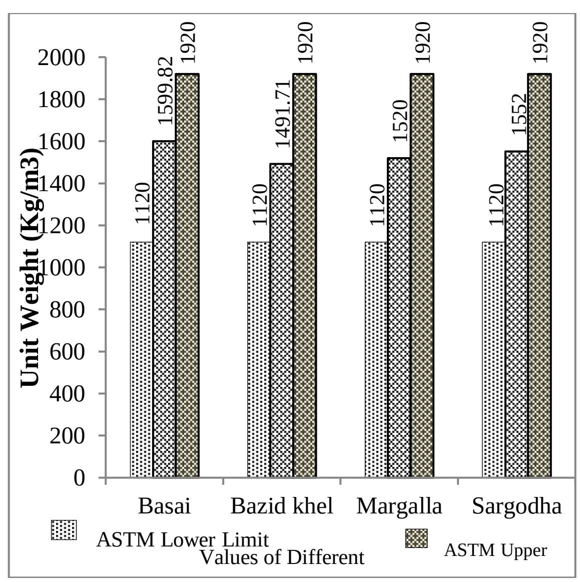

Fig. 5. Unit weight of coarse aggregates

C. Sieve Analysis of Coarse Aggregate:

The tests of sieve on coarse aggregate determine its particle size and its distribution through sieve analysis. The apparatus used for sieve analysis is a set of sieves, weighing balance, enamel tray, scoop, pan, and samples of coarse aggregates under test. In this study, sieve analysis of coarse aggregates was determined as per the standard of ASTM C-136 [17]. Gradation is the most important step in the sieve analysis experimental procedure. In gradation, the sample of coarse aggregate is segregated into different fractions based on the size of the many sieves. In this method, each fraction of the sieve contains particles of coarse aggregate according to specified limits. The coarse aggregate grading greatly influences the cohesiveness, strength, and durability of the concrete mix. It is obvious from the below figure that the sieve analysis of coarse aggregates source of erstwhile FATA, Margalla, and Sargodha sources are quite comparable.

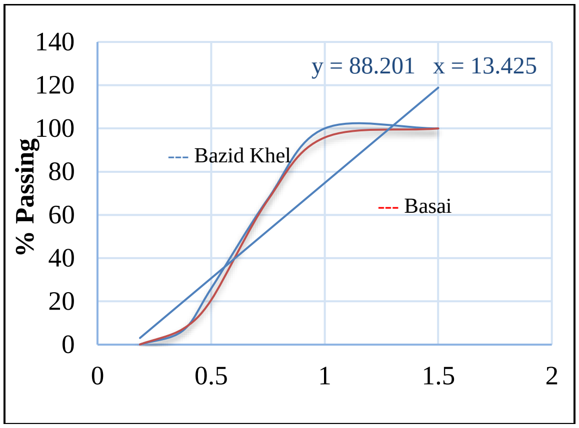

Fig.6. Coarse Aggregates Sieve Analysis Test

V. Mechanical Properties of Coarse Aggregates

The mechanical properties of aggregates were measured through ASTM standard test procedure:

- Soundness Test
- Los Angeles Abrasion.
- Compressive Strength.
- Indirect Tensile Strength.
- Crushing Strength.

A. Soundness Test of Coarse Aggregates:

This method was performed according to the standard of ASTM C-88 [22]. A value of material loss depends upon the type of soundness test applied. The Sodium Sulfate (Na_2SO_4), the value of solution limit is Zero to fifteen (0-15) percent. However, the Magnesium Sulfate ($MgSO_4$) solution's limit values are zero to thirty (0-30) percent. The soundness test of coarse aggregate samples obtained from Basai and Bazid Khel quarries is applied in the sodium sulphate solution. The soundness values of the samples collected from the two quarries are like that of Margalla and Sargodha aggregates which are commonly used in Pakistan and as per the ASTM limits.

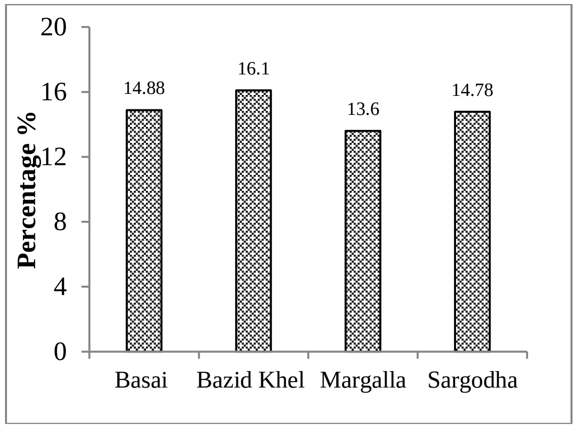

Fig. 7. Soundness Test of Coarse Aggregates

B. Los Angeles Abrasion Test of Coarse Aggregates:

The prerequisite of the abrasion test, ASTM C-131, C-535 [18], includes that the coarse aggregate must be within the limit of ten to forty-five (10-45) percent. The coarse aggregates that are closer to ten in value are recorded as hard rocks while those aggregates that are closer to forty-five are recorded as soft rocks. The Basai and Bazid Khel areas coarse aggregate abrasion test values 19.87, 20.29 percent, respectively. The abrasion values show a very good resistance of sample coarse aggregate. Coarse aggregate of such value shows better abrasion resistance and is considered as hard rocks. It can be recommended for infrastructural concrete formation. It is obvious from the below figure that the abrasion values of aggregates from erstwhile FATA are parallel to Margalla and Sargodha aggregates and satisfy the ASTM limits.

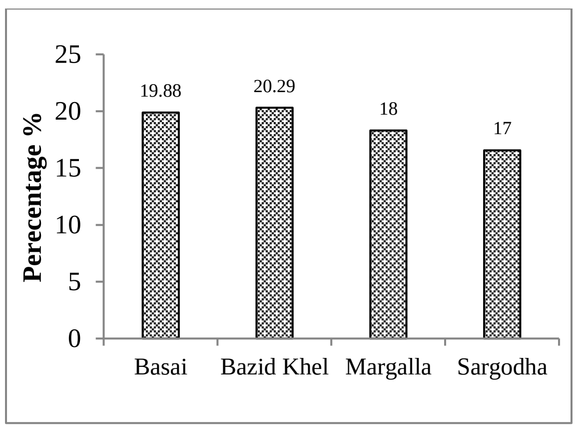

Fig.8. Abrasion Values of Coarse Aggregates

C. Compressive Strength of Coarse Aggregates:

Compressive strength, the ability of concrete to withstand specific compressive forces. Compressive strength is the most important property of concrete because some other strengths, such as abrasion, improve with an increase in compressive strength. In this study, Basai and Bazid Khel coarse aggregate specimen, which was in the shape of cylinders, were tested. These concrete cylinders' specimen compressive strength was checked after 28 days in saturated surface dry condition. The cylinders were tested according to ASTM C- 39-86 [23]. The compressive strength value of each tested sample is given in table 1. The values of compressive strength, three specimens of concrete made respectively of Basai and Bazid Khel aggregates, and Margalla and Sargodha aggregates are graphically shown in fig. 9. The cylinders samples of Basai and Bazid Khel aggregate show that the values of compressive strength greater than the Margalla and Sargodha aggregate's concretes.

Table 1: Compressive Strength of Concrete Cylinders

Concrete	Sample	Compressive Strength values, (MPa)	Splitting Tensile Strength values of concrete, (MPa)
Bazid Khel	Specimen-1	24.1	2.3
	Specimen-2	24.9	2.35
	Specimen-3	23.9	2.4
Basai	Specimen-1	23.9	2.3
	Specimen-2	24.5	2.2
	Specimen-3	23.5	2.25
Margalla	Specimen-1	23	2.18
	Specimen-2	25	2.21
	Specimen-3	24	2.24
Sargodha	Specimen-1	23	2.04
	Specimen-2	22	2.08
	Specimen-3	24	2.09

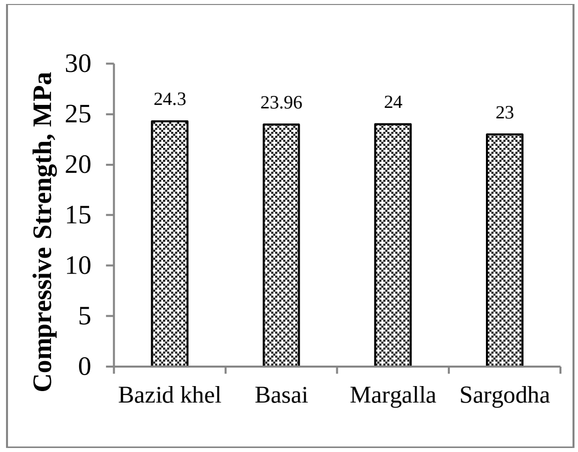

Fig. 9. Compressive Strength of Coarse Aggregates

D. Indirect Tensile Strength of Coarse Aggregates:

With the splitting tensile strength, the concrete can survive under tension load. Normally the concrete has greater compressive strength as compared to tensile strength. In this study, a cylindrical specimen of 150 mm diameter x 300 mm in height test undertaken the standard procedure of ASTM C-496 [19]. The specimen was kept in water for 28 days, and after that, it was tested. For each composition, three cylindrical samples of concrete were tested. The recorded value of each sample is shown in Table-1. Overall, Margalla, Sargodha, Bazid Khel, and Basai quarries are tested, and the data are all presented in fig 10. The results show that Basai and Bazid Khel quarries presented greater values in indirect tensile tests and are found more satisfactory among all the different samples.

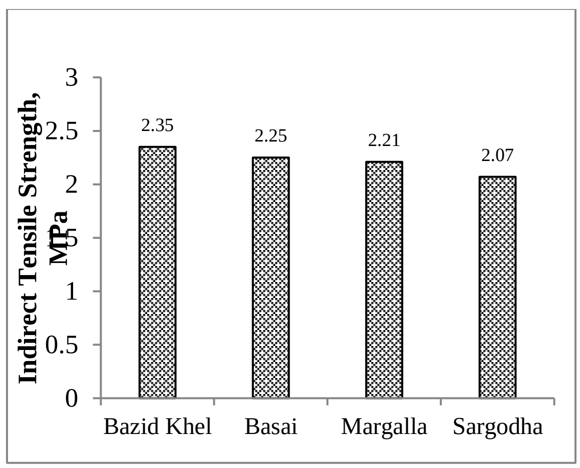

Fig.10. Indirect Tensile Strength of Aggregates

E. Crushing Strength Values of Coarse Aggregates:
Results of crushing strength values for different aggregates are summarized in Table 2. Crushing strength values of aggregates less than 30% are acceptable. The lower the crushing values, the stronger the aggregates will be. Aggregate Crushing strength value test IS Code is 2386-4 (1963) [20]. Fig. 11 shows that Sargodha aggregates have a minimum crushing value of 18.3 % and are the strongest among all. Margalla aggregates have a maximum crushing value of 28.5 %, which can be considered weaker than Sargodha. Basai and Bazid Khel areas have crushing values closer to Margalla aggregates. In general, all four aggregates showed satisfactory results against the crushing strength limit of 30 percent.

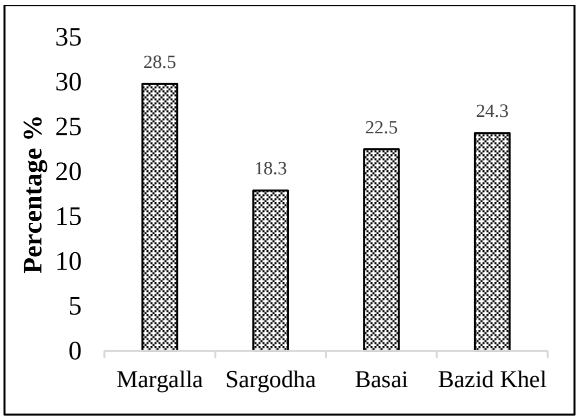

Fig.11. Crushing Strength Values of Aggregates

Table 2: Mechanical Properties of Coarse Aggregates.

Test	Margalla	Sargodha	Basai	Bazid Khel
Soundness Test (%)	13.6	14.78	14.88	16.1
Los Angeles Abrasion (%)	18	17	19.88	20.29
Compressive Strength (MPa)	24	23	23.96	24.30
Indirect Tensile Strength (MPa)	2.21	2.07	2.25	2.35
Crushing strength (%)	28.50	18.30	22.50	24.30

VI. Results and Discussion:

In a construction project, the cost of the project remarkably decreases when the construction material of required properties is available quite nearby. When the availability of suitable and appropriate material such as coarse aggregate is far from the construction site, construction materials cost significantly increased due to transportation. Most of the construction projects in the erstwhile FATA and Peshawar area use the coarse aggregate of Sargodha and Margalla. In contrast, the coarse aggregate available in Bazid Khel and Basai is very near to Peshawar and erstwhile FATA. Bazid Khel is forty-three kilometres away from Peshawar city. Similarly, Basai is also closer to Peshawar than Sargodha and Margalla. It is just eighteen kilometres away from Peshawar city. According to ASTM standard procedures, physical properties tests of Bazid Khel and Basai areas are sieve analysis, Specific gravity, Unit weight, and water absorption of coarse aggregates. The coarse aggregate results showed that the aggregates are under the ASTM range and are comparable with the approved sources of Sargodha and Margalla. Water absorption values of Bazid Khel and Basai, along with the approved sources of Sargodha and Margalla quarries, are within the limits of the ASTM range. The Unit weight test of coarse aggregates of Basai and Bazid Khel quarries is found within the ASTM range. Basai aggregates show maximum unit weight in the other three sources, but the Bazid Khel aggregates are like Margalla and Sargodha coarse aggregates. Mechanical properties of coarse aggregates of Basai and Bazid Khel, five fundamental tests like Los Angeles Abrasion test, soundness test, compressive strength test, split tensile test, and crushing strength were carried out in the laboratories. It is found that the coarse aggregate of Bazid Khel quarries showed a high level of compressive strength. Concrete samples made of Basai quarries coarse aggregate compressive strength are closer to the value concrete samples made of Margalla and Sargodha coarse aggregate. The value of split tensile strength of Basai quarries coarse aggregate and Bazid Khel coarse aggregate are also very encouraging. It showed a greater value of indirect tensile strength. Similarly, the soundness value of sample concretes of Basai and Bazid Khel coarse concrete is considered satisfactory when compared to Margalla and Sargodha aggregate concrete. So, both quarries Basai and Bazid Khel, are similar with an approved source of Pakistan. Los Angeles Abrasion values of aggregates, Basai and Bazid Khel having the value of in range as per ASTM standard, and both the aggregates recommended for use in structural concrete as compared to Margalla and Sargodha aggregates. The results show the aggregates source's crushing strength values were found satisfactory against the approved crushing strength limit of 30 percent.

VII. CONCLUSION

The present study illustrates the experimental results of aggregates selected from different sources within Margalla and Sargodha quarries. For determination, the physical and mechanical properties, tests were conducted to investigate the aggregates in detail. Bazid Khel and Basai coarse aggregate are found good in quality. Therefore, it can be suggested to use it with confidence. It is also found that Basai and Bazid Khel coarse aggregate produce similar properties. Compressive strength split tensile strength, soundness of coarse aggregate, Los Angeles abrasion test, and Crushing strength values are as per the ASTM standard and approved coarse aggregates. These findings will assist the executing agencies in identifying the aggregates from low to high quality of construction.

Similarly, Basai and Bazid Khel aggregates may be used in road construction with high traffic loads due to their good impact and crushing strength. In comparison to Sargodha and Margalla, the transportation cost is meagre. Future works include developing guidelines and preparing maps based on a geographic information system that can provide reliable information for the contractors and executing agencies to use the locally inexpensive materials.

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