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Aggregate Suitability Assessment of Wargal Limestone for Pavement Construction in Pakistan

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Abstract

This paper presents the evaluation of the potential aggregate source for pavement construction in Pakistan. Recently the demand for construction materials has been increased significantly due to the establishment of the China-Pakistan Economic Corridor (CPEC) Projects. Therefore, it is essential to look for new resources of construction materials along with the CPEC routes in consideration of this increasing demand. In this context, a Physical and Mechanical characterization investigation is carried out on the Permian Wargal Limestone from Zaluch Nala, Salt Range to explore their potential to utilize as construction materials. The studied samples have tolerable values for all standard engineering parameters, proposed by various national and international agencies such as AASHTO, ASTM, BS, and NHA. Furthermore, as a performance indicator of aggregate overall quality, the evaluated mechanical qualities were integrated into a single characteristic, Toughness Index (TI). The TI values also suggested that the Permian Wargal limestone aggregates meet international quality standards for pavement construction. On the basis of geotechnical testing and Toughness Index (TI), the late Permian Wargal limestone, Zaluch Nala, Salt Range, is strongly recommended as a potential aggregate resource for mega projects such as the China-Pakistan Economic Corridor (CPEC) and other construction projects.

Keywords

CPEC, Potential Aggregates, Geotechnical Properties, Toughness Index (TI),

Wargal Limestone

1. Introduction

Aggregate refers to any coarse to medium-grained material formed from natural (igneous, sedimentary, or metamorphic rocks) or artificial (geosynthetic aggregates) materials, depending on the source and method of use. Aggregate is the most common material used in pavement construction [1]. Aggregate mixes must sustain plastic deformation and have a high resilience modulus to withstand traffic impacts (stiffness) [2]. Aggregates must also be resistant to disintegration and weathering in situ, be free of plastic particles, and drain well [3]. Quarrying rocks and then crushing them to the proper size is the primary method of producing aggregates in Pakistan [4] [5]. Several factors to consider when selecting and recognizing the qualities of aggregates are of great importance to pavement engineers when designing pavement construction [6]. An aggregate must meet a "specification" before being used as a road-making material. Specifications from the United Kingdom or the United States are often employed.

In Pakistan, an extensive intercity network of roads and highways acts as the country's backbone, accounting for about 96% of freight movement. The extensive use of aggregate is essential to productivity and economic development in developed countries [7]. The majority of roads are in poor condition and need up up-gradation in Pakistan. In addition to other national development initiatives, new highways, roads, and other infrastructure are necessary to expedite nation-building activities [8]. Pakistan has a total area of 796,095 sq.km and a population of more than 208 million (Census - 2019) [9], with a comprehensive road network of 228.026 km. Commercial, individual, private, and government building is in full swing, backed by Pakistan National Highways Authority (NHA) [10]. Aggregate demand is increasing due to infrastructure activities, which necessitates mapping new resources and their potential evaluation [11]. Limestone is often utilized as a raw material for aggregates, owing to its widespread availability and extensive usage in the construction and cement industries. Limestone aggregates are produced in Punjab and Khyber Pakhtunkhwa by quarrying and crushing rocks [4]. The Salt Range is dominated by Permian carbonates, located close to CPEC routs. The China-Pakistan Economic Corridor (CPEC) is a massive project that connects more than 70 nations through Pakistan's Gwadar port (**Figure 1**). Many long-term and short-term projects, including roads, railway lines, and fiber optic installations, are part of the CPEC project. Tunnels and bridges are also included in these lines. Furthermore, this project consists of both large and small building constructions [12] [13] [14] [15]. For such mega projects, vast reserves of the potential aggregate materials are required. In order to meet this need, various high-quality limestones are exposed at various locations along the CPEC's western route [16]. Hazara, Mansehra, Margallah Hill limestone, Samana Suk limestone, Kawagarh limestone, and Lockhart limestone are available in bulk amounts that can be used as potential aggregates [16]. In contrast, the central parts of the CPEC crossing through the Salt Range (**Figure 1**) and the Trans Indus ranges are well-stocked with Wargal limestone, Samana Suk limestone, and Sakesar limestone.

The late Permian Wargal limestone exposed near Zaluch Nala, Salt Range, was studied and evaluated to establish its potential as aggregate for construction purposes (**Figure 2**). The Wargal Limestone aggregates were tested for appropriateness by examining their resistance to abrasion caused by static, dynamic, permanent, and cyclic stresses. As a consequence, the following are the study objectives: 1) analyze the Wargal limestone mechanical characteristics, 2) calculate the Wargal limestone aggregates' Toughness Index (TI), 3) finally, information on the suitability of limestone in the local road and transportation sector will be provided.

2. Geology and Stratigraphy of the Area

The Salt Range, an active fold and thrust belt originated by the collision of the

Figure 1. Pakistan-China Economic Corridor (CPEC) Mega Projects Map in Pakistan Source (National Highway Authority).

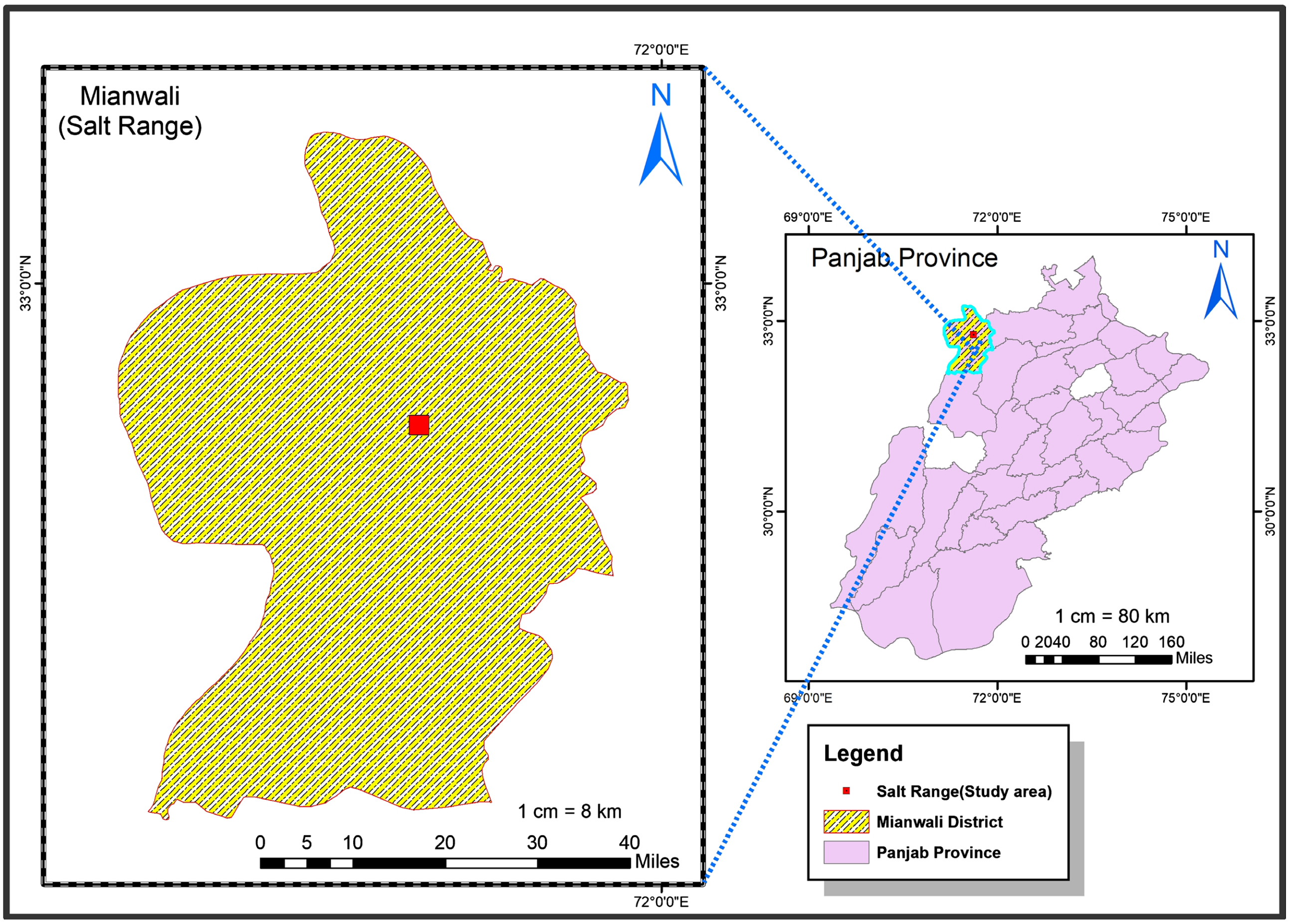

Figure 2. Location map of Wargal Limestone, Zaluch Nala, Western Salt Range, Panjab, Pakistan.

Indian and Eurasian plates, dominates the Indian Plate's northern border [17] [18]. The Indian and Eurasian plates crashed 55 million years ago because of the Indian Plate Northward drift [19] [20] [21]. The Salt Range Thrust is the Himalayan foreland system Southernmost fault and the system youngest compressional structure [22] [17]. Evaporites and overlying strata from the pre-Cambrian period cover the range front's syn-orogenic alluvium and fan material [21]. In the eastern Salt Range, the Precambrian Salt Range Formation is deposited on the younger strata (**Figure 3**). In contrast, the Carboniferous-Permian Nilawahan Group represents the oldest rocks exposed in the Western Salt Range [23] [24] [25]. The Salt Range contains rocks from the Precambrian to the Tertiary ages [26] [25]. The eastern, middle, and western sectors of the Salt Range include these rock units. The Salt Range Pakistan Carboniferous-Permian sequence separates the Gondwanan Lower Permian Nilawahan Group from the shallow marine Middle to Upper Permian Tethyan Zaluch Group [27] [28] [29].

Precambrian to recent strata make up the Salt Range stratigraphy (**Figure 4**), but the Ordovician, Silurian, Devonian, and Carboniferous strata were not found anywhere in the area [30]. The geologic succession of the Salt Range pushes out horizontally to extinction. While the Western Salt Range and the Trans Indus

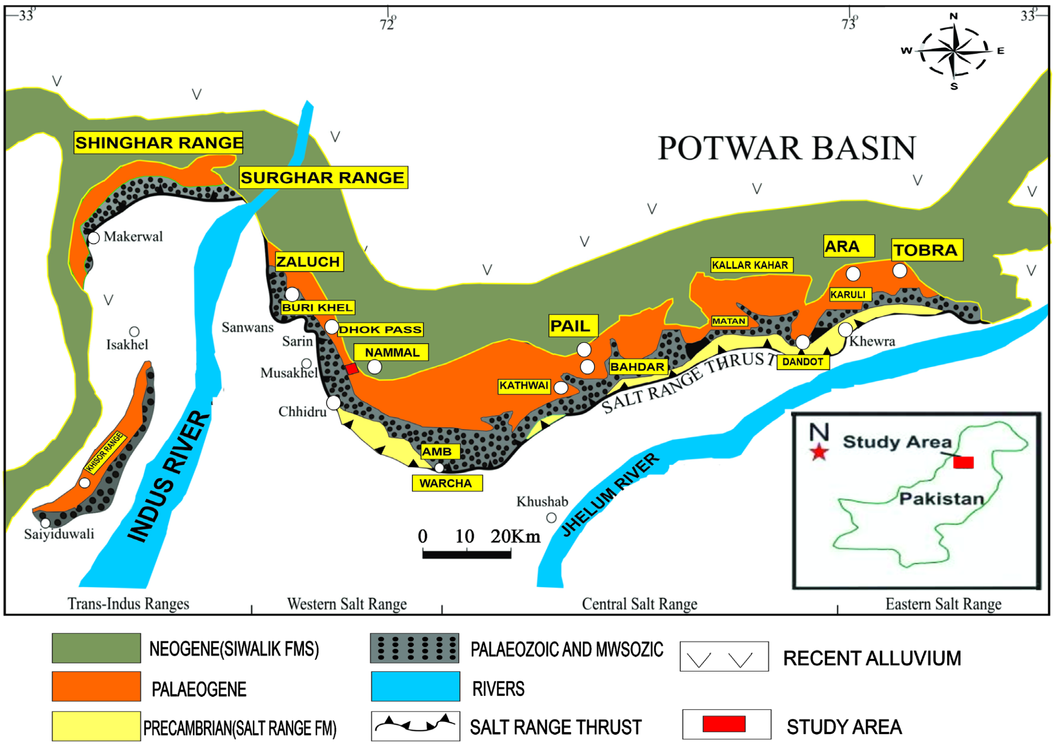

Figure 3. Geological map of Salt Range with the studied location of the Permian Wargal Limestone, Zaluch Nala, western Salt Range, Pakistan (Modified after Afzal and Butt, 2000).

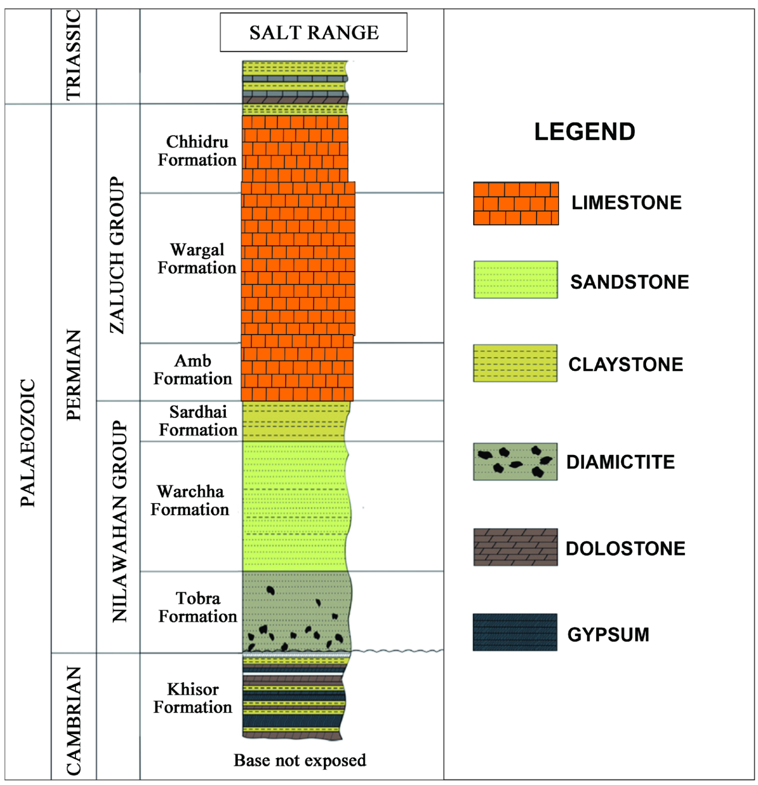

Figure 4. Simplified Carboniferous-Permian stratigraphy of the Zaluch Nala, Salt Range, Pakistan (Modified after Gee, 1989; Jan *et al.* 2009).

Ranges have a well-developed Mesozoic sequence, the Triassic and perhaps all Cretaceous strata are noticeably absent from most Central and Eastern Salt Range [31]. Nilawahan Group, Tobra Formation, Dandot Formation, Warchha Sandstone, and Sardhai Formation are younger Paleozoic rocks of the lower Permain age. The Permo-Cambrian Unconformity lies between the Jhelum Group's Baghanwala Formation and the Nilawahan Group, Tobra Formation. Upper Permian Zaluch Group includes the marine siliciclastic-carbonate mixed lithofacies of the Amb Formation, Wargal Limestone, and Chhidru Limestone [31]. The PermoTriassic Boundary is marked by the Musakhel Group's Chhidru Formation and the overlying Mianwali Formation.

Nammal Gorge, western Salt Range, comprises a well-exposed portion of Wargal Limestone on an anticline faulted to the northeast (**Figure 3**). Wargal limestone was formerly known as "The Wargal Group", "Middle Products Limestone", and eventually as "Wargal limestone" when a Pakistani stratigraphic council formally named it. Namal gorge is the typical section of this formation. It is composed mainly of limestone and dolomite, which are almost grey. Limestone is argillaceous and crystalline, and it is often found interbedded with chert nodules and fossils in sandstone. Crystallized and fossiliferous, dolomite has a pinkish-grey color. Limestone and Dolomite comprise the lithology, composed of light to medium gray, brownish-grey, and olive-grey colors. The detailed lithology of the formation along the Zaluch Nala is about 130 m thick [32] [33]. The lithology changes over the thickness of Zaluch Nala.

The thickness of this formation is 183 m at the type locality, while the average thickness throughout the Khisor and Marwat Ranges is about 174 m. The boundary between the Wargal limestone and the underlying Amb formation is well defined. It is situated in the formation's basal sandy limestone above the topmost shale level of the Amb formation [34]. The upper contact with the Chhidru formation is transitional. Trilobites, Gastropods, and Bivalves fossils were found. Bryozoans, brachiopods, bivalves, gastropods, nautiloids, Ammonoids, trilobites, and crinoids are abundant in the fauna. The formation dated from the mid-Permian based on the fossils [35].

3. Methodology

Field and laboratory studies were done to investigate the Wargal limestone and determine their aggregate potential for construction purposes. Materials for laboratory analysis were acquired from the Wargal limestone, Zaluch Nala, Salt Range. The current research is carried out for aggregate (Coarse) at the China University of Geosciences, Wuhan, China.

3.1. Field Work

The research area has been visited to collect representative samples for lab examination. According to [36] standards, block and crushed samples are the most common methods for collecting samples. Many characteristics were evaluated to determine geological suitability, workability, and economic potential, including lithology, texture, particle shape, color, bedding pattern, thickness, fauna, and lateral extension. Samples were taken from the Permian Wargal limestone, Salt Range, at equal intervals (**Figure 2**). All samples acquired were subjected to laboratory tests for hardness, toughness, specific gravity and porosity, shape test, chemical test, and bitumen test evaluation.

3.2. Laboratory Tests

The samples were subjected to various geotechnical tests using standard techniques advanced by the (ASTM-2014). Under the established standards, physical/Mechanical and chemical testing was conducted on all five representative samples to select decent quality and performance-bound aggregate usage in the construction sector. It is necessary to characterize the aggregate. Physical/Mechanical and chemical testing was performed to meet the required specifications [37]. Each sample was tested five times to minimize errors and facilitate reliable results.

3.2.1. Aggregates Hardness Tests

Aggregate resistance to crushing and abrasion is measured by their hardness [38]. Aggregates are crushed and subjected to abrasive wear during the pavement layers' production, installation, and compaction. Pavement layers are also subjected to abrasion under traffic pressures [39]. They must withstand crushing, degradation, and disintegration to some extent. The hardness of aggregates near the pavement surface must be higher because they are subjected to increased stresses, and the aggregate can come into direct contact with the wheel. Aggregate contact stress is lower in the pavement lower layers [40]. Several significant and relevant hardness properties were examined to evaluate the quality of rock samples for usage as aggregates in pavement construction. These properties include Aggregate Crushing Value (ACV) [41], Los Angeles Abrasion (LAA) [42] test, and the 10% Fines Value (TFV) [43].

1) Crushing Value of Aggregate

An aggregate's ability to withstand crushing under a gradually increasing compressive force is the primary goal of this test Crushing and resistance to crushing under traffic wheel load are the primary goal of this test [44] [45]. High-crushing aggregates are considered to be excellent at bearing with compressive forces [46]. ACV directly influences pavement stability; the pavement will break easily if the poor aggregate is used. The ACV is calculated using the British Standard method [47]. Strong aggregates have an ACV of about 5%, whereas weaker aggregates have 30%. The loading has a detrimental effect on the findings because weak rocks produce so many fines particles during testing. It is more appropriate to use the TFV value on such weak rock.

2) Los Angles Abrasion Test

The LAA (dry) test measures aggregates' abrasion and impact resistance. It's carried out in accordance with (T-96, 2004). LAAT limitations for aggregates are

35 percent, 40 percent, and 50 percent of cement concrete, base course, and sub-base, respectively.

3) Ten Percent Fine Value

The TFV test determines the required force to form 10% particles from an aggregate sample held in a steel mold. It was executed in accord with [43]. The higher the value, the more difficult it is to crush the aggregate [48]. According to US and UK standards, it is not acceptable for the TFV to be less than 50 kN. It has been used to illustrate the usage of the Toughness Index. It is important to note that TFV requirements may vary from 50 to 110 kN, with a maximum of 160 kN [3]. Equation (1) was used to find out the result.

$$F = \frac{14f}{m+4} \tag{1}$$

where,

f is the maximum force (in KN);

m is the percentage of material passing the 2.36 mm test sieve at the maximum force.

Table 1 presents the data of these "hardness" tests. The table shows that Wargal limestone aggregates are suitable for usage in all pavement layers in terms of hardness.

3.2.2. Aggregates Toughness Tests

The aggregate's toughness refers to its ability to withstand impact forces [49]. Pavement aggregates should be hard enough to endure pounding or wheel load impact without fracturing [50]. The Aggregate Impact Value (AIV) test determines aggregates' ability to withstand a sudden impact [51]. The results are shown in **Table 2**. A lower AIV indicates higher impact resistance. AIV less than 10% is

Table 1. Standard base values of aggregate according to AASHTO.

Test	Base value
LAAV	Base Course ≤ 50%
	Cement Concrete ≤ 16%
	Surface course ≤ 30%
	very strong < 10%
AIV	Very strong >10% - ≤20%
	Wearing course < 30%
	Base Course < 45%
ACV	Good aggregate < 45%
	Wearing course < 30%
W.A	Good aggregate < 0.6%
S.p Gravity	Good aggregate ≥2.6 - ≤2.9
Soundness Test	Max 12% for Na2 and 18% for Mgso4

Table 2. LA, AIV, ACV, Load to TFV, SG and TI of Analyzed Permian Wargal Limestone, Salt Range Pakistan

Sample No.	Los Angles Abrasion %	TFV (kN)	Specific Gravity %	Water absorption %	Crushing value %	Aggregate Impact value %
1	14.6	94.1 ± 2.0	2.55	0.74	15.96	11.08
2	13.9	93.2 ± 3.2	2.46	0.85	14.70	13.67
3	15.4	94.5 ± 1.5	2.99	0.42	13.01	11.40
4	13.1	95.5 ± 3.5	2.82	0.80	14.68	10.41
5	14.6	93.5 ± 3.8	2.85	0.65	15.00	12.17
Average	14.32	94 ± 2.8	2.73	0.69	14.67	11.75

outstanding, AIV between 10% and 20% is acceptable, and AIV more than 35% is only suited for lower layers [52].

3.2.3. Specific Gravity and Porosity (Water Absorption)

Bulk specific gravity (SG) is the weight of an aggregate in air divided by the weight of an equivalent volume of distilled water. Aggregate quality and strength can be assessed using SG [3] [53]. Specific gravity and water absorption values can determine aggregate strength and water absorption capacity [54]. Aggregates used in pavements have SG values ranging from 2.6 to 2.7, with a maximum of 2.9.

The porosity of an aggregate is a measurement of the interconnecting air spaces in a particle that is evaluated by determining how much water it absorbs when submerged in water [55]. Porosity is desirable because it allows bitumen to soak into aggregate particles and produce a mechanical contact between the bitumen film and the stone particle. A porous and weathering-prone aggregate is considered a non-suitable aggregate. A weaker or poor aggregate has low specific gravity and a high water absorption rate, while a suitable aggregate has the opposite characteristics [56]. The specific gravity and water absorption are calculated using a standard approach [57]. The result of the specific gravity and water absorption is shown in **Table 2**.

3.2.4. Shape Test of Aggregate

The shape of the particles also plays a significant role in determining an aggregate's behavior and appropriateness. Internal interlock increases the stability of angular aggregate [3] [58]. Elongated or flaky material particles should not be utilized because they are difficult to compress and have a high air void content in situ. Internal friction in the aggregates impedes particle mobility, which is dictated by the shapes of the particles [59]. Particle shape properties are determined using the tests mentioned below.

1) Flakiness Index (FI) Test

The Flakiness Index measures the proportion of the sample's total weight that passes through the flaky gauge's apertures (FI). It was done according to the standards [60]. The primary purpose of this test is to assess the shape of individual particles, as approximately spherical particles are more robust. The total weight of the aggregate that passed through the gauge's aperture was calculated and reported as a percentage of the overall sample weight. The workability of a road is affected by deformation and breaking of aggregate under high traffic loads [54] [61]. FI value of less than 45 percent is deemed adequate for the surface and lower layers (ASTM: D-693-28).

2) Elongation Index (EI) Test

The weight of an aggregate-based sample held in an elongated gauge is used to calculate the proportion of elongated particles [16]. This test was performed by [62]. Elongated particles have low strength. The elongation index of crushed particles is 1.5 times bigger than the flakiness index [63]. An aggregate with less than 45 percent EI can be used on the surface and lower layers. **Table 2** summarizes the findings of particle shape testing. Results show that aggregates from the study area are appropriate for use in both surfaces and lower layer purposes.

3.2.5. Chemical Tests for Aggregate

Soundness Test

Soundness quickly determines an aggregate's ability to withstand weathering and erosion. We can easily achieve aggregates by using a soundness test which can deteriorate under various weathering circumstances, such as moisture, freeze, and thaw [64]. Sodium sulfate is a common chemical used to test aggregate soundness. Weathering conditions like freezing, wetting, drying, and temperature variations damage the aggregate's structure in the field and have a direct impact on a civil construction project's life [10] [16] [65]. Aggregate quality should be rugged and durable enough to withstand weathering and erosion [4]. The specified limit for this test is 12%. The results are shown in **Figure 5**.

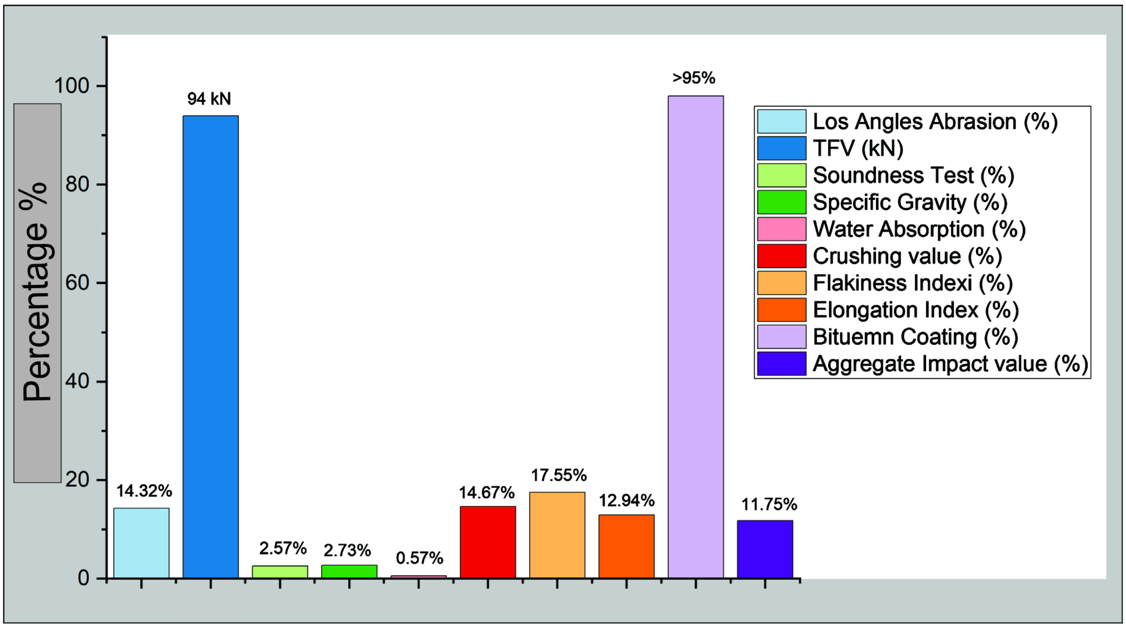

Figure 5. Engineering properties of potential aggregate resources from Zaluch Nala, Salt Range, Pakistan.

3.2.6. Bitumen Coating and Stripping of Aggregate

A regulated temperature of roughly 25˚C is necessary for this test to determine the coating properties of an aggregate with the bituminous binding material [66]. Bitumen grades 60/70 and 80/100 were employed in this test. A good blend of binder (Bitumen) and aggregate components will be obtained in aggregate with increased coating and striping value, which eventually strengthens and extends the life of any civil building [67]. Under the action of water and moisture, asphalt aggregate must maintain a thin coating of bitumen on its surface [61]. The test results are shown in **Figure 5**.

3.2.7. Toughness Index (TI)

The mechanical properties of the aggregates were better represented by [3] establishing a classification of aggregates based on a mechanical index; it is based on the measured values of LA, AI, AC, TF, and SG (**Figure 6**).

The method for calculating TI is outlined below. **Table 3** lists the hardness values used to standardize aggregate hardness data for this research. The British Standard specifies the maximum values for each attribute. The goal is to define

Table 3. Aggregate specification Source: Based on Kamal *et al.* (2006).

TI Range	Rating	Use
>97	Very Good	Road Surfacing and Base
95 - 97	Good	Base and Subbase
90 - 95	Fair	Subbase Only
<90	Poor	Use with caution

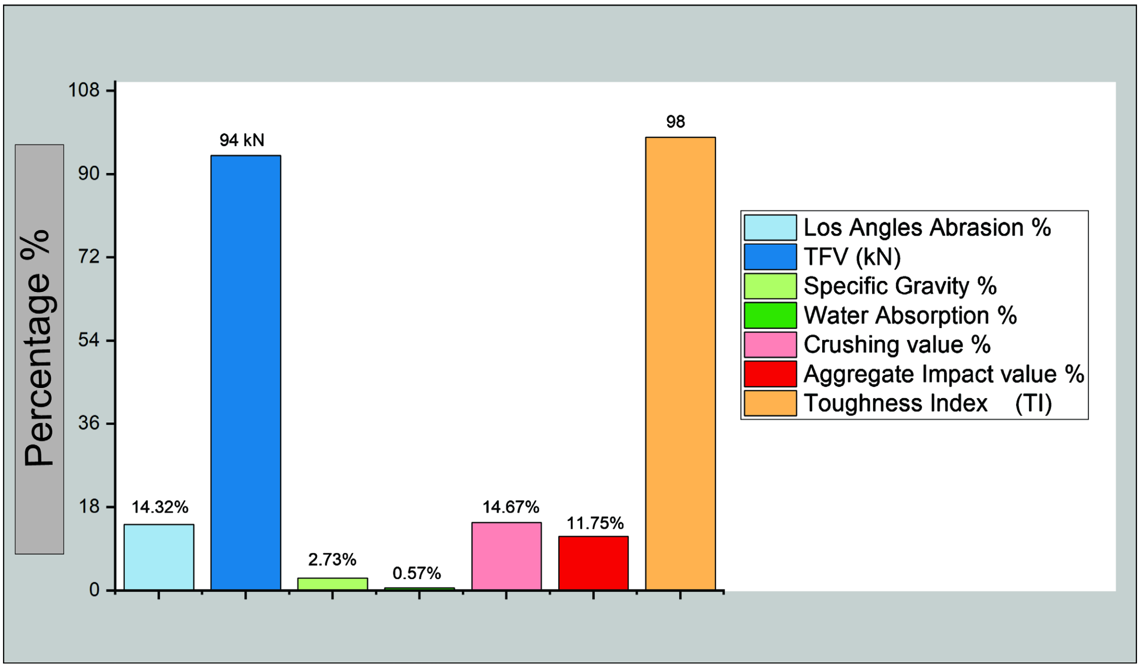

Figure 6. Toughness Index of Aggregate from Zaulch Nala, Salt Range Pakistan.

a TI on a scale of 1 - 100 to specify the aggregate's total strength from a single source [3]. As in the case of CBR, the calculated TI may be more than 100. The TI is calculated from the given Equation (2).

$$\mathrm{TI} = \frac{A+B+C+D+E}{5} \tag{2}$$

where,

$$A = 1.1 \times \frac{\mathrm{SG}}{2.9} \times 100$$

$$B = \mathrm{IF\ ACV} \le 30 = 100 \quad \mathrm{OR}$$

$$B = \mathrm{IF}\left(\mathrm{ACV} > 30\right) = \frac{100 - \mathrm{ACV}}{\left(100 - 30\right)100}$$

$$C = \mathrm{IF\ TFV} \ge 50 = 100 \quad \mathrm{OR}$$

$$C = \mathrm{IF}\left(\mathrm{TFV} < 50\right) = \frac{\mathrm{TFV}}{50 \times 100}$$

$$D = \frac{100 - \mathrm{LAAV}}{100 - 15 \times 100}$$

$$E = \mathrm{IF\ AIV} \le 30 = 0.9 \times 100 \quad \mathrm{OR}$$

$$E = \mathrm{IF}\left(\mathrm{AIV} > 30\right) = 0.9 \times \frac{100 - \mathrm{AIV}}{\left(100 - 30\right)100}$$

On this basis, the TI for aggregates in this research has been determined and is shown in **Figure 6**.

4. Result and Discussion

Results of various tests on Wargal Limestone aggregate are compared to the standard values of AASHTO, ASTM, and the National Highway Authority Pakistan, established by Road Research and Material Testing Institute Punjab (**Table 1**). To assess whether Wargal limestone is appropriate for road aggregate, the standard values are applied and compared to the analyzed values of the limestone.

The standard value for the LA test for Sub Base is 50%, the base course is 40%, and the concrete is 35%. The results obtained for the LAA test are 14.32% (**Table 2**), which is within the acceptable range of concrete (**Table 1**). The assessed Wargal limestone samples are permitted as concrete, base course, sub base, and surface course (**Table 1**). The Wargal limestone has a low LAA value, is rated the hardest aggregate, and is best suited for base and surface courses. The maximum ACV for the Base course should be 45%, and the maximum ACV for the Surface course should be 35%; the result of the tested samples is 14.67% (**Table 2**). Based on these values, the analyzed value is within acceptable ranges. Wargal limestone can be used as a base and surface course, subbase, and concrete aggregate (**Table 1**). The TFV test shows the aggregates' needed load to create 10% fines [3]. The Wargal limestones required a load more than 90 kN, which is within the permissible range of the stipulated maximum in US and UK regulations. The standard values for AIV are characterized as follows: 10% extremely strong, >10% - 20% strong, >20% - 30% acceptable for the road surface, while the maximum limit for base course is 45%. According to AIV, the analyzed sample value was recorded 11.75% (**Table 2**), and it is suited for road surface and Base Course and fall within the range of strong aggregate (**Table 1**). Wargal limestone is the hardest aggregate suited for use in a landslide-prone environment because it has a low AIV. The water absorption test value was recorded 0.57% (**Table 2**) for the analyzed limestone sample, and the standard value should be ≤0.60% (**Table 1**). Wargal limestone demonstrates the lowest absorption limit. According to the results, Wargal limestone is robust and non-porous. Specific gravity indicates a rock's strength, and high specific gravity values indicate a strong rock. The recommended Specific gravity value falls in the range of ≥2.6 - ≤2.9 **Table 1**, with examined samples value was recorded 2.73 **Table 2**, Wargal limestone is recommended as an excellent aggregate based on comparisons.

Based on Equation (1), Toughness Index TI values for aggregate samples in the present study have been calculated and are presented in **Figure 6**. Toughness index (TI), a unique value, can be used as a performance indicator for the aggregates [3]. According to classification **Table 3**, aggregates with the TI values less than 90 can be considered poor quality and, therefore, can be either avoided or used with proper caution. In this study, the values of TI were found > 90 and are recommended as very good aggregate in quality, and it is suitable for pavement construction purposes.

The average value of the flakiness index is 17.55% **Figure 5**. These findings are within the specified ranges, indicating that the aggregate under investigation could be utilized in concrete and asphalt. Elongation index test average results value was recorded of 12.94% **Figure 5**. The findings are well within the standard specified limit (15 percent Max), indicating that the aggregate under consideration could be utilized safely in asphalt and cement concrete. According to ASTM standards, the recommended value for Soundness Test (ST) is an average weight loss on each sieve of no more than 12%; the assessed value of Wargal limestone was 2.57% **Figure 5**. Wargal limestone is resistive to freezing and thawing cycles of weathering because values are less than 12 percent **Table 1**, based on the result the Wargal limestone recommended for aggregate potential. The stripping Value of all the samples of Wargal limestone was below 5% using 80/100-grade bitumen, and the coating value was recorded above 95% **Figure 5**. The values of coating and striping of bitumen are comparable with international standards and designate Wargal limestone as an excellent source for potential aggregate.

All Engineering Test Results and toughness Index (TI) show that the studied samples of Wargal limestone excellently qualify the acceptable ranges of these engineering parameters as allowed by different Agencies like AASHTO (2009), ASTM (2004), BS (1990), and NHA (1998) for the base course, sub-base course, asphalt, and cement concretes. The values of these parameters are excellently comparable with other good quality aggregates sources exposed in Margalla Hill, Kirana complex, and adjacent areas in Pakistan [54] [61].

5. Conclusion

The paper emphasizes the potential of Wargal limestones, which are located in the Salt Range of Pakistan, to be exploited as an aggregate source for engineering projects. Various laboratory tests were performed to establish the physical and mechanical properties of the Wargal limestone. Values of physical parameters were compared mutually with BS and ASTM standards for their qualification as an aggregate source for the construction industry. The physical, chemical and mechanical properties of Wargal limestone are well in accordance with international standards and therefore highly recommended for pavement and transportation uses. The Wargal limestone aggregate showed excellent bitumen affinity, so it's strongly recommended for road surfacing. The Toughness Index (TI), represents a unified mechanical property to classify aggregates for pavement construction, and it highly recommends the Wargal limestone as the best potential aggregate source. Our analysis and laboratory tests suggest that all physical properties of the Wargal limestone are within the acceptable ranges and it is strongly recommended as a potential aggregate resource for mega projects such as the China-Pakistan Economic Corridor (CPEC) and other local infrastructure and industrial zones. Limestone is easily available and transportable to many areas. Open-pit excavation is a simple way to mine limestone. Mining should be carried out in an environmentally sustainable way.

Future Work

Unconfined compression test (UCS), Ultimate Tensile test (UTS), and other lab experiments are recommended for the better analysis of Wargal limestone. In order to utilize Wargal limestone in all kinds of construction work, more inquiry into the occurrence history of aggregate samples, their structural behavior, and Petrographic analysis is advised. Remote sensing-based mapping is needed to distinguish between the various lithological differences in the region (*i.e.*, Limestone, Dolomite, Sandstone, etc.). The expansion of crushing operations in the region will result in a massive quantity of potential aggregate for development.

Acknowledgments

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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