Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X Volume 3, Issue 11, 2025

FEASIBILITY STUDY OF THE ANDESITE'S AND GRANITES EXPOSED IN THE GHIZAR DISTRICT, GILGIT-BALTISTAN BY USING PETROGRAPHIC AND PHYSIO-MECHANICAL APPROACHES

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DOI: https://doi.org/10.5281/zenodo.17510426

Keywords
Construction materials, Aggregates, Mechanical properties, Geotechnical Properties, Concrete Production, Kohistan Island Arc, Petrography

Article History
Received: 12 September 2025
Accepted: 22 October 2025
Published: 03 November 2025

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Abstract
Present study focuses on the petrographic and physio-mechanical viability of the volcanic and plutonic igneous rocks (andesite and granites) exposed in the north-western district of Gilgit-Baltistan, for its usage as coarse aggregate in construction work. Geologically, the investigated area lies along the collisional zone between Eurasian Plate and Kohistan Island Arc, that is why rocks along this boundary are highly deformed and metamorphosed. Exposed rock types include basalts, andesite, granites, meta-igneous and meta-sedimentary. Bulk rock samples were collected from different quarries of andesites and granites for detail physio-mechanical investigations. Petrographic observation reveals that the investigated rock samples are comprised of quartz, biotite, hornblende, epidote, muscovite and plagioclase. Most of the quartz grains exhibited undulose extinction, representing deformation of the quartz grains as a result of active tectonic activities. Physio-mechanical properties of these rock samples were acquired as per national and international standards i.e., American Society for Testing Material (ASTM), American Association of state Highway (AASHTO) and National Highway Authority (NHA) Specifications. It has been noticed that the analytical data observed from sieve analysis, specific gravity, absorption, porosity, flakiness and elongation, Los Angeles abrasion, and soundness lies in the acceptable and specified limits. Petrographic investigation demarcates that the exceeded percentage of deformed/reactive silica (i.e., >10%) in most of the inspected samples claims that these samples are not feasible for coarse and fine aggregates in concrete work. Reactive silica accelerates reaction between silica and concrete, causes weak bonding between concrete and aggregate, ultimately result in failure of major structures.

1. Introduction

Rock fragments or grains extracted from quarries undergo processes such as crushing, sizing, washing, or remain in their natural state to become aggregates. These aggregates, including sand, gravel, and crushed stone, are combined with binding materials to produce concrete, mortar, and asphalt (Langer, 2003). Aggregates constitute approximately two thirds of the total volume in concrete mixes (Ashkan, 2014). They can be categorized into natural or synthetic types, with coarse aggregates retained on 4.75 mm sieves, and fine aggregates passing through these sieves. In a typical concrete mix, aggregates make up 60% to 80% of the total volume, underscoring their critical role in ensuring efficiency, consistency in strength, workability, and durability (Ibearugbulem and Igwilo, 2019). Thus, the quality of aggregates is paramount in construction. Beyond their cost-effectiveness, aggregates enhance concrete's dimensional stability and resistance to wear. These properties significantly influence concrete's mechanical strength, performance, and longevity (Ayub et al., 2012). Natural aggregates are derived from the weathering, abrasion, or crushing of rocks, with their physical and chemical characteristics influenced by factors such as origin, petrography, weathering, and chemical alterations. Key factors determining aggregate quality include grain size, texture, mineralogy, pore spaces, and weathering effects (Langer and Knepper, 1995). Aggregates typically originate from three main sources such as igneous, sedimentary, and metamorphic rocks. The present study focuses specifically on granitic and andesitic lithologies (igneous rock) from Ghizar District, Gilgit-Baltistan, to evaluation of their suitability as coarse aggregates for construction purposes.

A high-quality aggregate must possess strength, hardness, and cleanliness, with durable particles that are free from harmful chemicals, clay coatings, or other contaminants that could affect cement hydration or the bond between paste and aggregate (Steven et al., 2002). Therefore, aggregates obtained from gravel pits, riverbeds, or quarries must withstand abrasion, disintegration, crushing, and erosion (Ghaeezadeh et al., 2014). Aggregates used in construction projects, whether for roads or buildings, must effectively distribute loads from upper layers to the earth's surface (Umar et al., 2019). Their mechanical properties and performance during service are significantly influenced by their mineralogical composition and degree of alteration (Al-Oraimi et al., 2006; Yilmaz et al., 2011).

Previous work highlights several petrographic and mechanical controls on aggregate performance. The characteristics of building stones vary due to rock formation processes and subsequent metamorphic effects (Carvalho et al., 2013). Tectonic phases influence lithological characteristics, mineralogical assemblages, compressive strength, and response to weathering (Mustafa et al., 2015, 2016; Yarahmadi et al., 2018). Granite has been a popular building material since ancient times, requiring detailed knowledge of its strength properties for effective utilization (Yarahmadi et al., 2018; Sousa and Gonçalves, 2013).

Petrographic factors such as grain size, shape, orientation, and fissures significantly influence rock behavior (Rivas et al., 2000; Seo et al., 2002; Nasseri et al., 2005; Ingham, 2005; Sousa et al., 2005; Ray et al., 2006; Lindqvist et al., 2007; Hyslop and Albornoz-Parra, 2008; Nasseri and Mohanty, 2008; Xia et al., 2008; Nespereira et al., 2009; Vasconcelos and Lourenço, 2009; Silva and Simão, 2009; Sousa, 2013). Petrographic analysis, within specific environmental conditions, provides insights into mineralogical composition, origin, durability, and weathering resistance (Jamshidi et al., 2013). The mechanical properties of rocks, influenced by mineral composition, have been extensively studied (Torkan et al., 2016; Miskovsky et al., 2004), with weathering susceptibility affecting strength (Woo et al., 2006; Tiryaki and Dikmen, 2006; Karaca and Onargan, 2008; Sousa, 2013). Uniaxial compressive strength (UCS) is a key indicator for characterizing and classifying building and dimension stones (Zorlu et al., 2008; Dehghan et al., 2010), affected by petrographic variables (Ündül, 2016). Non-destructive tests like ultrasonic pulse wave velocity (UPV) and Schmidt hammer tests provide additional strength information influenced by grain size, micro-fractures, orientation, and mineralogy (Suarez del Rio et al., 2006; Sousa, 2014). Other factors affecting mechanical behavior include grain size distribution, orientation, weathering, durability, and porosity (Eberhardt et al., 1999; Prikryl, 2006; Sousa, 2013; Wong et al., 2006; Vasconcelos and Lourenço, 2009; Aydin and Basu, 2005; Yavuz et al., 2006; Fahimifar and Soroush, 2007; Ceryan et al., 2008; Labus, 2008). The present study contributes to evaluating the physical and mechanical properties of granitic rocks in Gilgit-Baltistan (GB), assessing their suitability for building materials and dimension stones arising from economic opportunities like the China Pakistan Economic Corridor (CPEC).

Despite extensive work on the petrographic and mechanical behavior of aggregates in various geological settings, there remains a lack of integrated, site-specific evaluations that combine petrographic analysis with standard physico-mechanical tests for the granitic and andesitic rocks of the Phandar area, Ghizar District, northern Pakistan. This knowledge gap limits the ability to assess their potential as high-quality construction materials. By considering the above-discussed research and the limited work on this region, the present study is designed to address these gaps through a comprehensive approach. The present study focuses to assess the suitability of granitic and andesitic rocks as coarse aggregates for construction purposes through 1) extensive fieldwork, for sample collection and observe key geological features, 2) petrographic analysis of the samples for determining the mineralogical composition, and 3) to evaluate the geotechnical and engineering properties of andesitic and granitic rocks according to national and international standards such as ASTM and NHA specifications.

The results of this work have practical implications for both scientific understanding and regional development. The investigation aims to examine the engineering and geotechnical characteristics of aggregates in the region, with findings directly applicable to regional construction projects and beneficial to the local community. The outcomes will be disseminated through publication in both national and international journals, serving as a valuable resource for local stakeholders, researchers, and students involved in geological and engineering studies. This research endeavors to provide practical insights and guidance for enhancing construction practices and infrastructure development in the area.

2. Geology of the study area

The studied area is situated in the vicinity of Phandar village in Ghizar District, Gilgit-Baltistan, at 36°47´05.28´´N (Latitude) and 73°97´45´´E (Longitude). The site is approximately 40 kilometers away from Gahkuch city. It lies on the steep slope of elevated terrain along a jeepable track and is deeply cut by a perennial stream of low discharge, where the rock unit is best exposed. Most of the rock mass is covered by soil layers and regolith. The area is intensely deformed by local and regional tectonic elements, as demonstrated by the variable bedding dip and strike values (Gansser, 1964).

The North Pakistan is composed of three main geotectonic domains. These are (1) the Asian Plate (2) Kohistan Island Arc and (3) the Indian Plate. In Pakistan, the Main Mantle thrust (MMT) forms the tectonic boundary between 2 and 3 and the Karakoran Thrust (MKT) forms the tectonic boundary between 1 and 2 (Tahirkheli et al., 1979). The Kohistan Arc is an intraoceanic arc that was formed above a north-dipping subduction zone as a result of the northward drift of the Indian Plate (Bard et al., 1979). The Shangla Blueschists melange occurs at the contact between the Indian Plate to the south and the Kohistan Arc to its north.

Geologically the study area lies in the western continuity of Karakoram Ranges along the hanging wall of Main Karakoram Thrust (MKT) System. MKT is a regional fault and suture zone between Kohistan Island Arc (south) and Eurasian Plate (north) (Seeber and Armbuster, 1981). The area has undergone through severe deformation and metamorphism as a product of the collision of KIA and Eurasian plates. The investigated rock unit is an integral part of the Kohistan Batholiths of the Kohistan Island arc sequence. The Kohistan Island Arc sequence is divided into metavolcanics, Kohistan Batholiths and mafic igneous intrusions. The Kohistan Batholiths are further categorized into three groups on the basis of metamorphism and deformations (Tahirkheli., 1979; Patriat and Achache., 1984; Searle et al., 1987; Dewey et al., 1989; Klootwijk et al., 1991; Le Pichon et al., 1992; Rowley, 1996; Yin and Harrison., 2000; Najman et al., 2001, 2003; Zhu et al., 2005; Ding et al., 2005; Aitchison et al., 2007; Heuberger et al., 2007; Khan et al., 2009). Pre-collisional batholiths are comprised of diorites and are highly metamorphosed in gneisses and granulites due to the Himalayan Orogenic Processes. The syn-orogenic phase of Kohistan Batholiths also exhibits metamorphism but low in grade than post-orogenic batholiths, representing metamorphism during Himalayan orogenic processes. Post orogenic batholiths are comprised of leucogranitic rock and is still unmetamorphosed as they were formed by the processes of crustal thickness after the collision of Indian Plate with Kohistan Island Arc (Tahirkheli., 1979; Patriat and Achache., 1984; Searle et al., 1987; Dewey et al., 1989; Klootwijk et al., 1991; Le Pichon et al., 1992; Rowley, 1996; Yin and Harrison., 2000; Najman et al., 2001, 2003; Zhu et al., 2005; Ding et al., 2005; Aitchison et al., 2007; Heuberger et al., 2007; Khan et al., 2009).

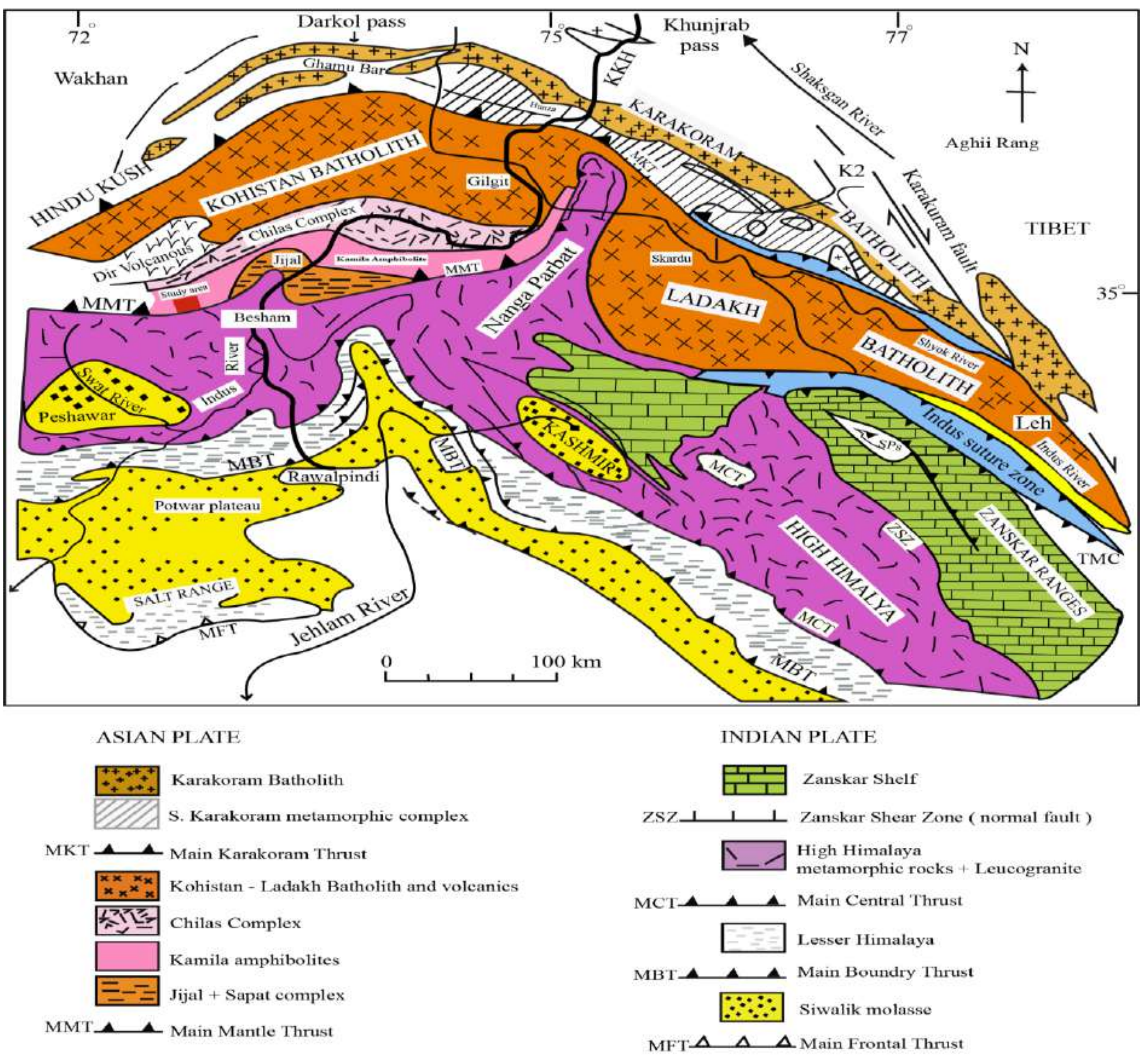


Figure 1. Geological Map showing the regional geology of studied area and northern sector, Pakistan (After Searle et al., 1999).

3. Materials and Method

3.1 Field Observation

Extensive fieldwork activity was conducted to collect rock representative samples and mark the inspected area on a map. During the field, random samples each weighing approximately 20 kg, were collected from the studied area in Ghizar District, Gilgit Baltistan. The representative rock samples were analyzed at the NASPAK Material Testing Laboratory in Mankial, Swat, and Khyber Pakhtunkhwa, Pakistan for geotechnical and engineering analysis. Tests were carried out following standards such as i) American Society for Testing and Materials (ASTM), ii) American Association of State Highway and Transportation Officials (AASHTO), British Standards (BS), and National Highway Authority (NHA). These tests included grading analysis, determination of specific gravity, assessment of water absorption, measurement of density, evaluation of porosity, determination of permeability, assessment of soundness, analysis of flakiness index, determination of elongation index, and Los Angeles abrasion test (LA test).

3.2 Laboratory work

Geotechnical investigation involves conducting different laboratory tests to identify the rock properties. These investigations are crucial for engineering projects like building foundations, roads, bridges, and dams. Some laboratory tests were performed for geotechnical investigations including Grading, Specific Gravity and Absorption, Elongation and Flakiness Index, Los Angeles Abrasion test, and Soundness.

4. Results and Discussion

Aggregates form a crucial component of concrete, constituting 60-80% of its volume, alongside cement (7-15%), water (14-18%), and air (2-8%). They are found in forms such as sand, gravel, and crushed stone, serving dual cost-effective roles in engineering projects by converting raw materials into usable components. The quality of concrete heavily relies on aggregates that must be devoid of clay, robust, clean, and free from cracks. Aggregates profoundly influence concrete's durability, strength, absorption, thermal properties, and workability (Langer and Knepper, 1995). A rough surface promotes strong bonding, whereas a smooth surface results in weaker bonding. To evaluate the engineering properties of aggregates for applications in constructions like roads and buildings, different samples were collected from the Phandar area, Ghizar District. Detailed mechanical assessments were conducted at the selected quarry, establishing connections between texture and geomechanical characteristics to ascertain suitability for specific construction uses. Aggregate characteristics hinge on the mineral composition and bedrock texture, with various analyses conducted and summarized findings discussed herein.

4.1 Field Observations

Detailed fieldwork was conducted for collection of samples and field features. Several quarries are working continuously, undertaking extensive exploration. To facilitate fieldwork investigations of the proposed rock unit, we utilized geological hammers, hand lenses, Brunton compasses, high-resolution cameras, sample bags, and the assistance of previous maps. Our main focus was on collecting random samples for petrographic study and for determining the geotechnical/engineering properties of the rock unit. During the fieldwork, our primary objective was to collect representative rock samples that accurately represented the spatial distribution and hosts for these igneous intrusions. Samples were collected randomly with care to capture the actual range of variations as well as other physical characteristics within these rock units. Special attention was given to sampling techniques, taking into account the variations in lithology, color, and grains appearance. Detail field observations were recorded, and features were captured in field photographs (Figure 2). It has been observed that the investigated granitic rocks are present in the form of batholith, intruded in Kohistan Island Arc sequence. These rocks are unmetamorphosed and exhibits coarse-grained texture (Figure 2A,B). As per literature the unmetamorphosed nature of these granitic intrusions represents its post orogenic origin. Granitic rocks are cross cutted by two sets of veins, composed of quartz and feldspar (Figure 2D). Quartz veins, represented by their white color, visible in the studied outcrops, suggesting later-stage hydrothermal activities. In the exposed outcrops, alteration zones in the form of iron leaching's were observed along the biotite and amphibole grains. It was evident that only chemical weathering caused alterations, leading to changes in color and textural variations in the studied rocks. Field observation plays a crucial role in providing valuable insights into the genesis of these granitic intrusions, contributing to a deeper understanding of its geological attributes and significance. Second rock unit encountered in this study is andesites (Figure 2C). These are intermediate volcanic rocks lying at the extreme northern periphery if Kohistan Island Arc. This rock unit is very fine-grained in which we cannot identify single mineral grains in hand specimens. It exhibits green to dark green color and are highly deformed (Figure 2C). By using hand lense, it was clearly observed that these rocks have undergone through regional dynamothermal metamorphism during the Himalayan orogenic processes.

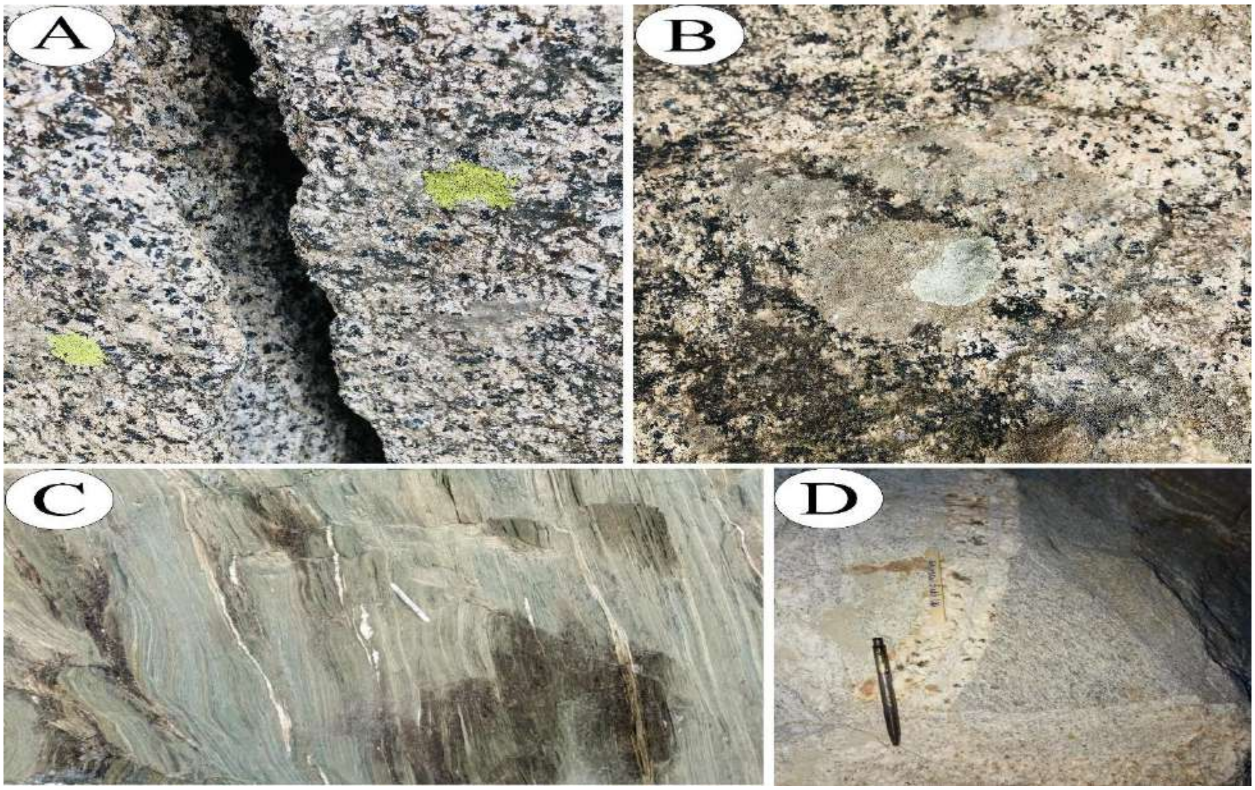


Figure 2. Field photographs exhibiting prominent features observed during detail outcrop investigations (A-B) Unmetamorphosed leucogranitic rocks, intruded in the Kohistan Islanad Arc sequence. The unmetamorphosed nature of these granitic batholith reflects their origin immediately after the collisiopn of Indian Plate with Kohistan Island Arc in the Himalayan Collisional Orogenic processess. The leuco nature of these grantic bodies demonstrati ng its genesis from the solidification of secondary magma, originated from partial meting as a product of crustal anatexis. (C) indicates the meta-andesites of the Chalt Volcanic group. Andesite represents the subduction of oceanic plate beneath continental plate, and eruption of the intermediate volcanic rocks along the margin of subduting or obduction plate. These volcanics are syn-orogenic but later on metamorphosed during the collision of Kohistan Islanad Arc with

Eurasian Plate. (D) represent two phases of magmatic activities. The cross cutting relationship and metamorphic and unmetamorphic nature of these teo rock exhibits their placement timings. The intruded leucopegmatitic grantic dyke is younger and is unmetamorphosed, while the host rock exhibits metamorphism and is older.

4.2 Petrography

Petrographic analysis of representative samples selected based on their physical properties observed during field inspection. As a critical component of engineering geology, petrography plays an important role in determining the suitability of rocks as aggregates, categorizing them, and evaluating their properties, as well as identifying the presence of undesirable constituents (Collins, 2002). The fundamental petrographic characteristics of rocks, including grain size, grain interlocking, void space, and mineral composition, have a profound impact on the physical and mechanical properties of aggregates (Shakoor and Bonelli, 1991). The importance of petrography in engineering projects lies in its ability to distinguish between primary and secondary rock components, and to elucidate the physical and chemical properties of aggregates. In the subsequent section, a comprehensive petrographic analysis of the selected rock samples is presented, providing detailed insights into their composition and properties.

Petrographic study was conducted on representative thin sections. The dominant mineral compositions of the studied thin sections comprise dominant minerals like quartz, biotite, and feldspar, along with accessory minerals such as pyroxene needles, epidote, and plagioclase (Figure 3-5). The texture of the rock is coarse-grained, with a notable presence of dark minerals (Figure 3A-D). The dominant minerals in the thin section are quartz, feldspar, and amphibole, which are common in many igneous and metamorphic rocks. Quartz makes up around 25-40% of the sample, appearing smoky whitish in plane-polarized light and grey white in cross-polarized light, with an angular shape (Figure 3A-C). Feldspar constitutes around 25-35%, appearing white, gray, brownish, or reddish yellowish in plane-polarized light and brown or reddish yellowish in cross-polarized light, with cleavages and a triclinic crystal system (Figure 3D; Figure 4AB). Plagioclase is present in the range of 15-20%, with low relief, cleavages, and a subhedral shape, appearing white-smoky in plane-polarized light and black and white (lined) in cross-polarized light (Figure 4AB). Amphibole makes up around 20-25%, with high relief, oblique cleavages, and a prismatic crystal shape, appearing green, brown, or blackish in plane-polarized light and orange in cross-polarized light (Figure 4C,D; Figure 5C,D). Pyroxene needles are present in the range of 5-10%, with fibers and needle-shaped crystals, appearing green, brown, or blackish in plane-polarized light and gray, white, or pale yellow in cross-polarized light (Figure 5A-C). Lastly, epidote constitutes around 0-10%, with moderate cleavages, relief, and a subdural shape, appearing greenish gray in plane-polarized light and light grayish in cross-polarized light (Figure 5D). These observations provide valuable insights into the mineral composition and textures of the rock sample, contributing to a comprehensive understanding of its petrographic characteristics (Figures 3-5).

Table 2. Illustrate visual percentage of different minerals observed in thin sections.

Section	Quartz %	Plagioclase %	Epidote %	feldspar %	Biotite %	Pyroxene %	Ore minerals %	Amphibole %
SIS-1	25	10	0	30	0	0	20	10

SIS-2	15	15	30	30	0	0	10	10
SIS-3	15	15	0	15	25	0	0	30
SIS-4	15	0	5	10	0	40	0	30

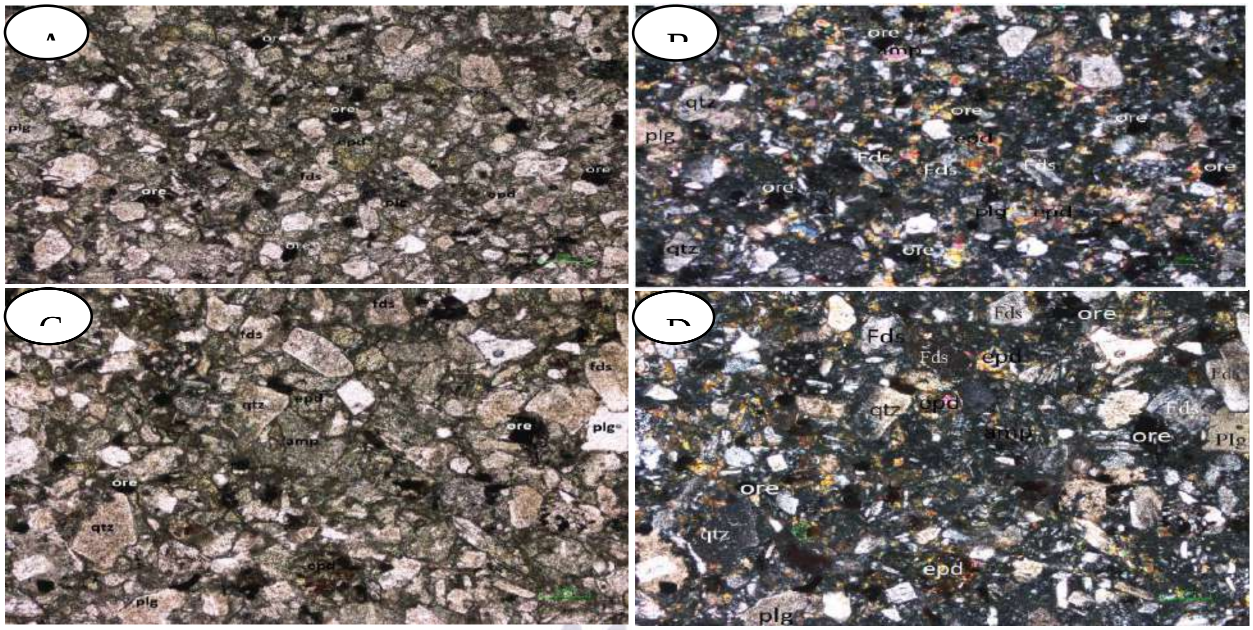


Figure 3. Plain and Cross light polarized light photomicrographs showing, (A-D) coarsely crystalline well developed euhedral of quartz scattered in fine grained chlorite, sericite and actinolite matrix. Opaque minerals were also identified as ore minerals. Plagioclase laths are also present in the representative samples, exhibiting twinning.

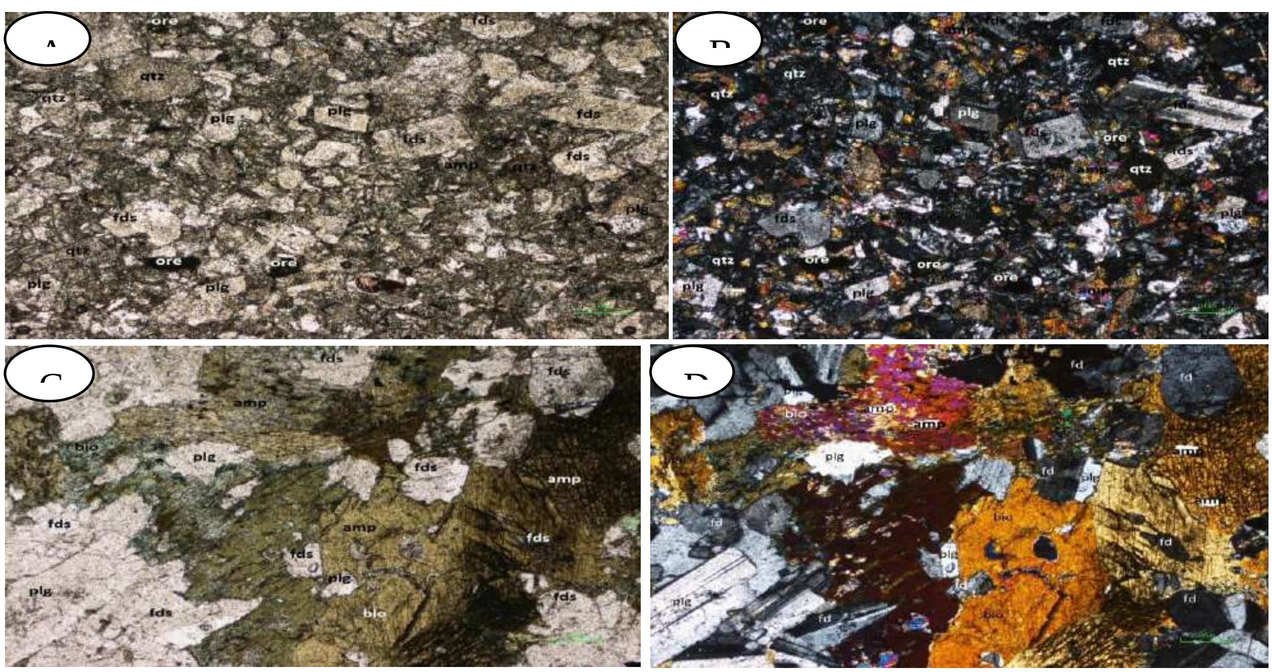


Figure 4. Plain and Cross light polarized light photomicrographs showing, (A-B) coarsely crystalline well developed euhedral-subhedral grains of quartz were observed as floating in the finely crystalline matrix of chlorite, sericite and actinolite matrix. Few opaque minerals were also identified as ore minerals. Larger plagioclase laths are also present in the representative samples, exhibiting twinning. Quartz grains exhibit undulose extinction, demonstrating deformed quartz as a result of the tectonic stress during Himalayan Orogeny. Photomicrographs of the standard sample Showing Plan Polarized light and Cross Polarized Light, (C-D) Larger crystals of amphibole were observed in association with feldspar-plagioclase and quartz grains.

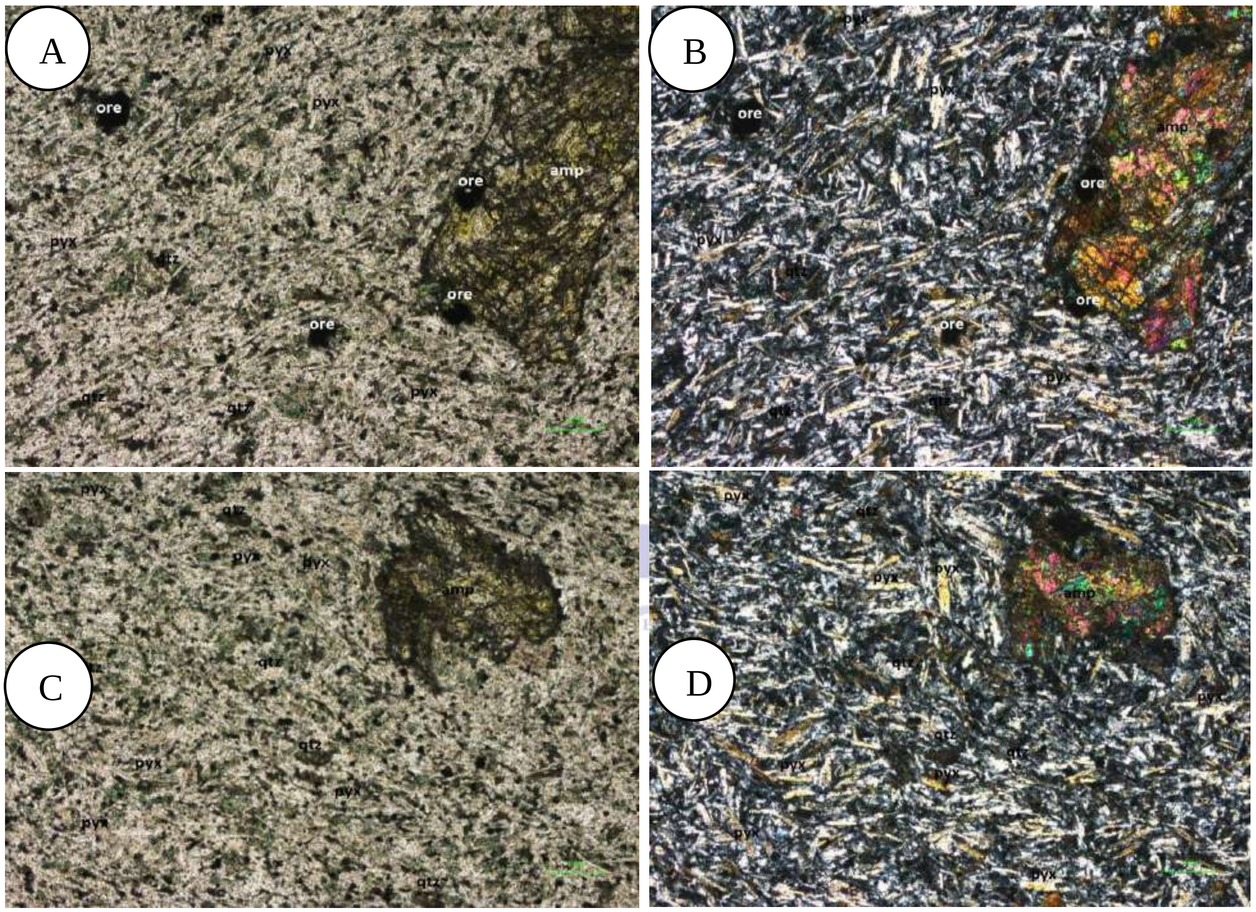


Figure 5. Plain and Cross light polarized light photomicrographs showing, (A-D) Finely crystalline matrix comprised of quartz, feldspar, actinolite and amphibole. Larger amphibole crystal is present as porphyroblast in the regionally metamorphosed andesitic rock, representing metamorphic origin. Pyroxene crystals were also identified, reflecting its intermediate composition.

4.3 Physical and Mechanical Properties

The mechanical properties of the studied rocks i.e., andesitic and granitic rocks, are influenced by factors such as mineralogy, texture, structure, and weathering. These characteristics are pivotal in determining how these rocks respond mechanically. This study focused on investigating the physical and mechanical properties of granitic and andesitic rocks through a range of physio-mechanical tests. These tests included gradation analysis, porosity measurement, bulk density determination, water absorption tests, flakiness and elongation index assessments, soundness tests, and Los Angeles abrasion tests. These tests collectively provide insights into the behavior of the rocks and their suitability for specific engineering applications. Each test evaluates different aspects like physical and mechanical characteristics of the rocks, helping to measure their durability, strength, and performance under various conditions.

4.3.1 Grading / Sieve analysis

Sieve analysis was conducted on the coarse aggregate of the studied sample. The method is used for the distribution of the rock samples based on particle size. Grading is the basic analysis for classification of course and fine aggregates. The grading analysis results declare coarse aggregates as the passing percentage is 7.3.

Table 3. Result of Gradation and sieve analysis for coarse aggregate.

Sieve size (inch)	Sieve size (mm)	Retained wt. (g)	Cumulative retained wt. (g)	Retained %age	Passing %age	Specification
2	50.8	Nil	Nil	-	100	100
1/2	38.1	115	115	6.3	81.6	90-100
1	25.4	150	290	12.5	76.9	80-92
3/4	19.1	225	470	23.8	60.6	55-75
1/2	12.7	210	700	34.5	49.2	35-50
3/8	9.52	360	1000	55.3	26.2	25-40
#4	4.75	280	1234	93.2	7.3	10-20

Calculation:

Passing % = 100 Retained %
Retained % = 93.2
Passing % = 100-93.2
Passing % = 7.3

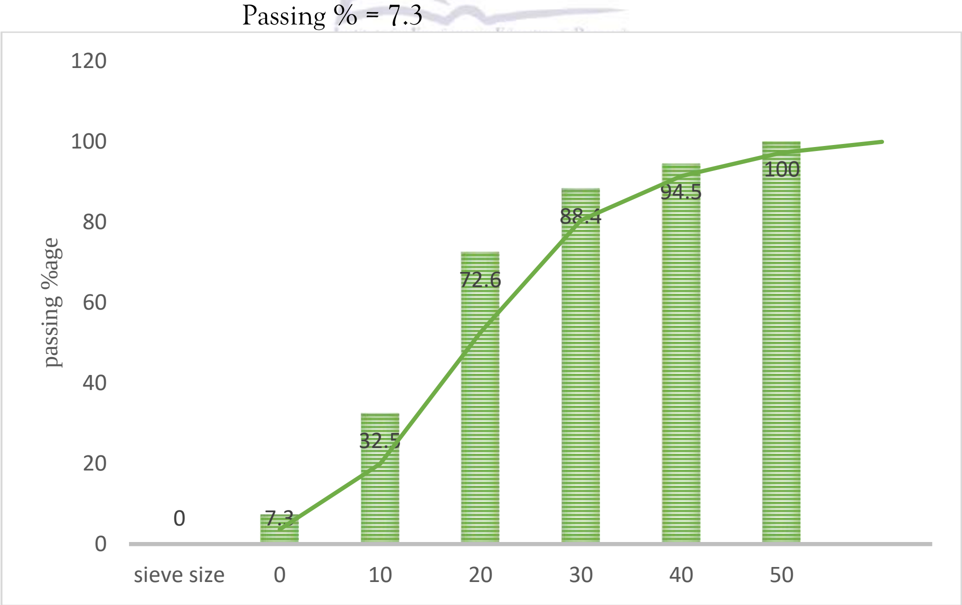


Figure 6. Gradation and sieve analysis for coarse aggregate.

4.3.2 Fineness modulus

Fineness modulus specifies the aggregates properties, it is directly related to the concrete aggregate strength (Sabih et al., 2016). The fineness modulus of the coarse aggregate falls within the range of 6.0 to 8.5. Specifically, the coarse aggregate in the investigated sample has a fineness modulus of 7.37, falls within the specified limits of ASTM, indicating its suitability for use as coarse aggregate in various construction purposes.

$$Finess\ Modulus\ Total\ Retained = \frac{Total\ retained\% + 500}{100}$$

$$Finess\ Modulus = \frac{747.1}{100}$$

Fineness Modulus = 7.31%

4.3.3 Bulk Density (ASTM C-29, AASHTO T-19)

When comparing the compacted (rodded) and uncompact (loose) states, variations in bulk density or unit weight of coarse aggregate are observed. According to NHA specifications (1988), high-quality aggregate should have a rodded value ranging from 1.4 to 1.7, and un-rodded (loose) value between 1.3 and 1.7. In this study, the rodded bulk density of the coarse aggregate sample measures 1.57, while the loose bulk density is determined to be 1.47. These findings indicate that the coarse aggregate meets the specified criteria for good quality as per NHA standards.

Formula for bulk density and unit weight.

$$M = \frac{G - T}{V}$$

G= mass/weight of aggregate
T=mass /weight of measure
V= Volume of measure
Formula for void contents:

$$Voids\% = 100 \times \frac{(S \times W - M)}{(S \times W)}$$

Where,
M= Bulk density of aggregate
S=Bulk specific gravity
W= Density of water

4.3.4 Specific Gravity (ASTM C-127, AASHTO T-85)

In heavy construction operations, aggregates with a specific gravity of 2.800 or above are deemed appropriate (Blyth et al., 1994). Specific gravity is critical in assessing the strength and durability of rock materials. Engineers frequently favor materials with higher specific gravity for construction due to their superior strength and density characteristics. In this study, the specific gravity analysis of the coarse aggregate yielded a value of 3.006 g/cm³ (Table 5). This consistent value with minor variations reinforces its suitability for heavy construction projects, confirming its robust density and strength properties.

4.3.5 Absorption

When assessing the stability and durability of various rocks for construction materials, water absorption is a crucial factor (Shakoor et al., 1991). Bell (2007) defines high-quality rock and aggregate as having a water absorption value of less than 1% by weight. According to NHA specifications, coarse aggregate should have a water absorption value of less than 1%, while fine aggregate should be less than 3%. In this study, the analysis of the rock sample revealed a water absorption percentage of 0.448% (Table 5), which falls well below the 1% threshold. This finding suggests that the rock and aggregate possess low water absorption characteristics, indicating their suitability for construction. This attribute contributes significantly to their stability and durability when used in building applications.

To calculate water absorption, the following equation was used:

$$Water\ Absorption\% = \left(\frac{W1 - W2}{W2}\right) \times 100$$

Where W1 represented the weight of surface-dried aggregate, and W2 represented the weight of oven-dried aggregate after cooling.

$$\text{Absorption\%} = \frac{Surface\ saturated\ dry\ weight - oven\ dry\ weight}{Oven\ dry\ weight} \times 100$$

Table 4. Calculation procedure for bulk and apparent specific gravity and water absorption of coarse aggregate.

A	Weight of saturated surface Dry samples (SSD) (g)	3295 g
B	Weight of samples in water (g)	7285.5 g
C	Weight of Oven Dry Samples (g)	6123.6 g
D	Bulk Specific Gravity (Oven Dry). C / (A - B)	2.525 g
E	Bulk Specific Gravity (SSD). A / (A - B)	1.654 g
F	Apparent Specific Gravity C / (C - B)	1.581 g
G	Absorption (%). (A - C) / C × 100	2.970%

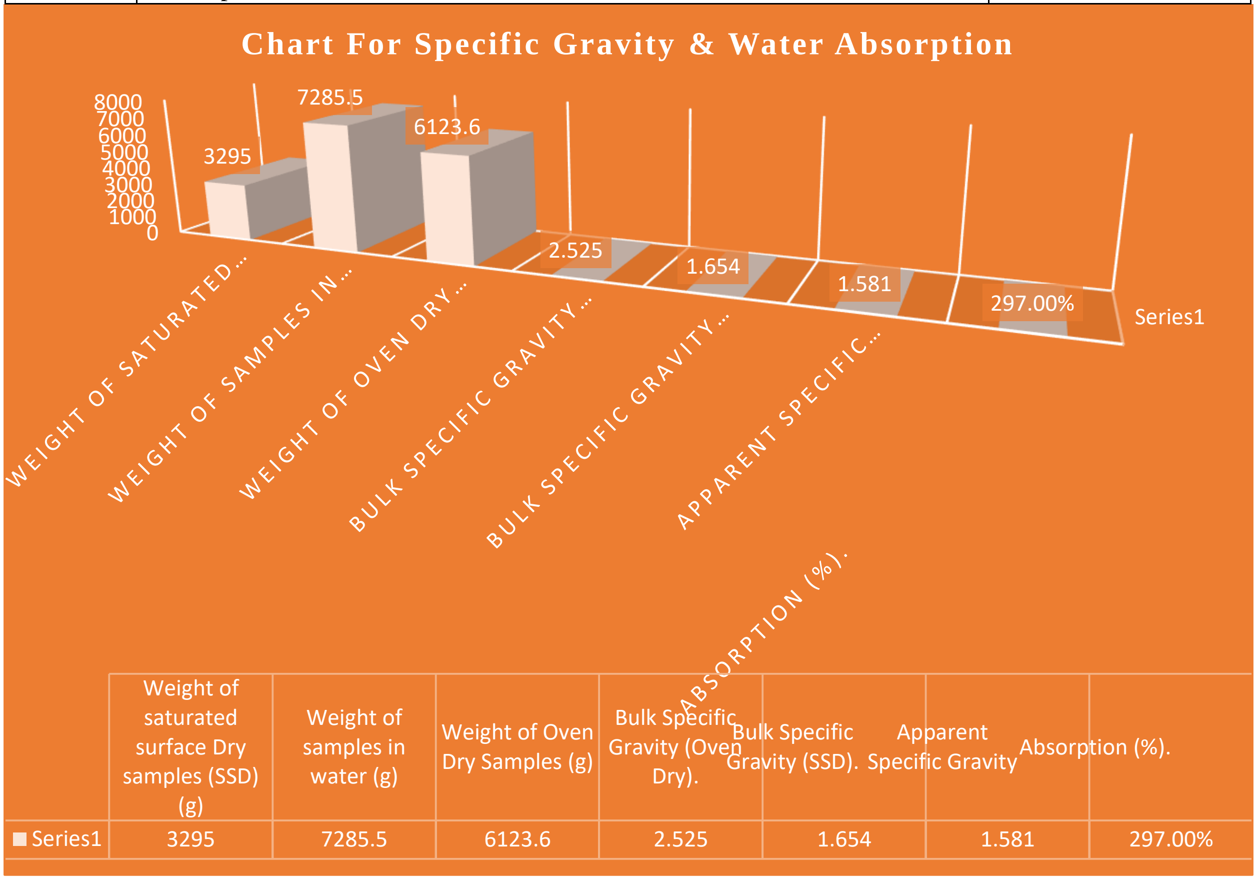


Figure 7. Specific gravity and water absorption (ASTM, AASHTO-19)

4.3.6 Porosity

Porosity is the amount of void spaces or pores within rocks, is a key factor influencing their strength. The size, shape, and distribution of rock grains also contribute significantly to porosity (Nimmo, 2004). This physical attribute is essential in geotechnical and engineering analyses, providing valuable insights into the composition and suitability of rocks for different construction and engineering applications. In this study, the porosity of the investigated rock sample was found to be 2.93% (Table 5).

Mathematical Formula

$$Porosity = \frac{SSD\ wt. - Dry\ wt.}{SSD\ wt. - wt.\ in\ water} \times 10$$

OR

$$Porosity = \frac{wt.\ in\ air - oven\ dry\ wet}{wt.\ in\ air - wt.\ in\ water} \times 100$$

Table 5. Result of specific gravity, water absorption and porosity test of coarse aggregate.

A	Oven dry sample in Air (A)	1615.0
B	Saturated surface dry sample in Air (B)	1622.4
C	Saturated surface dry sample in water (c)	1085.1
D	Specific Gravity Bulk A/(B-C)	3.006
E	Specific Gravity Bulk SSD B/(B-C)	2.020
F	Specific Gravity Apparent A/(A-C)	3.048
G	Absorption % (B-C) /A× 100	0.448
H	Porosity B-A / B-C× 100	2.93

4.3.7 Flakiness & Elongation Index Test (AASHTO M-80), (ASTM C-125)

The Flakiness and Elongation Index Test, guided by AASHTO M-80 and ASTM C-125 standards, establishes a maximum limit of 15% for coarse aggregates ((Khan et al., 2025). If the Flakiness and Elongation Index surpass this threshold, the aggregates are considered unsuitable for construction purposes. This test is essential for verifying the quality and appropriateness of aggregates utilized in diverse construction activities. The value of the studied samples is within the range, so they are suitable for construction purposes (Table. 6). In this study, the flakiness index value is 7.55% and the elongation index value is 4.94%, both values fall below 15% (permissible limit), indicating that the tested aggregates are suitable for use in construction due to their favorable particle shape characteristics (Table 6).

Table 6. Result of Flakiness and Elongation Index for Coarse Aggregate

Sieve Size	Flakiness Index		Elongation Index	
Sieve No.	Weight of aggregate	Weight of passing on	Weight of none flaky	Wt. of aggregate each fraction retained on
	Taken in grams (A)	Thickness gauge (B)	Retained on Thickness gauge (C)	Length gauge (D)
1 Inch	1000.0	70.o	0.0	1.0
34	2000.0	28.0	700.0	99.0
½ Inch	2000.0	80.0	3000.0	204.7
3/8 Inch	500.0	93.0	3000.0	89.0
Total	5400.0	261.0	5400.o	289.9

$$Flakiness\ Index = \frac{wt.of\ passing\ on\ the\ thickness\ gauge\ (B)}{wt.of\ aggregate\ taken\ in\ grams\ (B)}$$

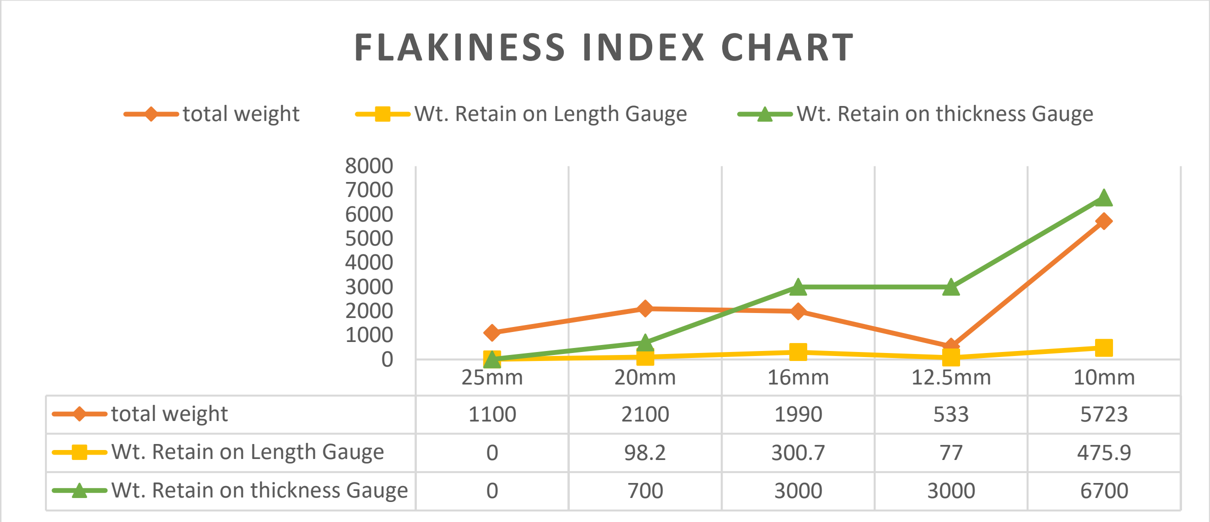
$$Flakiness\ Index = \frac{478.1}{5500.0}$$

Flakiness Index = 7.55 %

$$Elongation\ Index = \frac{wt.of\ aggregate\ fraction\ retained\ on\ length\ gauge\ (D)}{wt.of\ non\ flacky\ retained\ on\ thickness\ gauge\ (C)} \times 100$$

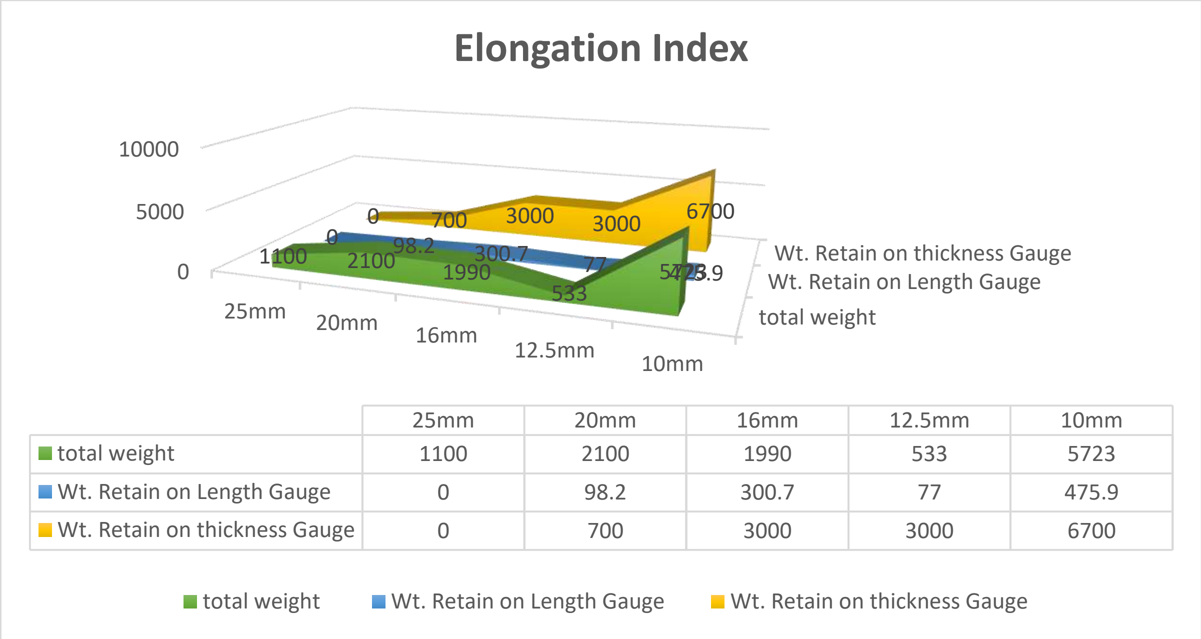
$$Elongation\ Index = \frac{264.7}{5500.0} \times 100$$

Elongation index % = 4.94%



	25mm	20mm	16mm	12.5mm	10mm
total weight	1100	2100	1990	533	5723
Wt. Retain on Length Gauge	0	98.2	300.7	77	475.9
Wt. Retain on thickness Gauge	0	700	3000	3000	6700

Figure 8. Flakiness index test (AASHTO M-80, ASTM C-125)



	25mm	20mm	16mm	12.5mm	10mm
total weight	1100	2100	1990	533	5723
Wt. Retain on Length Gauge	0	98.2	300.7	77	475.9
Wt. Retain on thickness Gauge	0	700	3000	3000	6700

Figure 9. Elongation index test (AASHTO M-80, ASTM C-125)

4.3.8 Soundness (STM C88-13)

Test of Aggregates by the use of Sodium Sulphate, also known as AASHTO T- 104 or ASTM C-88, is a standard test method used to assess the durability and potential deleterious expansion of aggregates when subjected to repeated cycles of wetting and drying. This test helps to determine the soundness or stability of aggregates when exposed to moisture, which is important for ensuring the long-term performance of concrete and asphalt moistures. The soundness of aggregates refers to their ability to resist volume changes due to the expansion and contraction, caused by repeated cycles of wetting and drying. Aggregates that undergo significant volume changes during these cycles are considered unsound and may lead to cracking and premature deterioration of concrete or asphalt in construction projects. To evaluate the soundness of aggregates, the Sodium Sulphate Soundness Test, standardized by AASHTO T-104 (American Association of State Highway and Transportation Officials) and ASTM C-88 (American Society for Testing and Materials), is commonly used.

Formula for Soundness Test:

Loss in weight =Weight of aggregate before the test-Weight of aggregate after the test Percentage loss =Loss in weight/Weight of aggregate before test x 100

Actual loss =Retain% of original gradation percentage loss ÷ 100

Table 7. Soundness test (ASTM C88-13) results showing weight loss of coarse aggregates after repeated

Passing Sieves (inch)	Retained Sieves (inch)	Ret% of Original Gradation	Wt. of Agg. Before Test	Wt. of Agg. After test	Loss in Wt. (g) B-C	%age Loss D/C × 100	Actual Loss % A×E/ 100
-	-	A	B	C	D	E	F
$2^{1/2}$	$1^{1/2}$	10	5000	4860	140	2.80	0.28
$1^{1/2}$	3/4	20	1500	1450	50	3.33	0.666
¼	3/8	20	1000	975	25	2.50	1.50
3/8	#4	40	300	290	10	3.33	2.448
				Total Loss % Coarse Aggregate			2.448%

wetting and drying cycles.

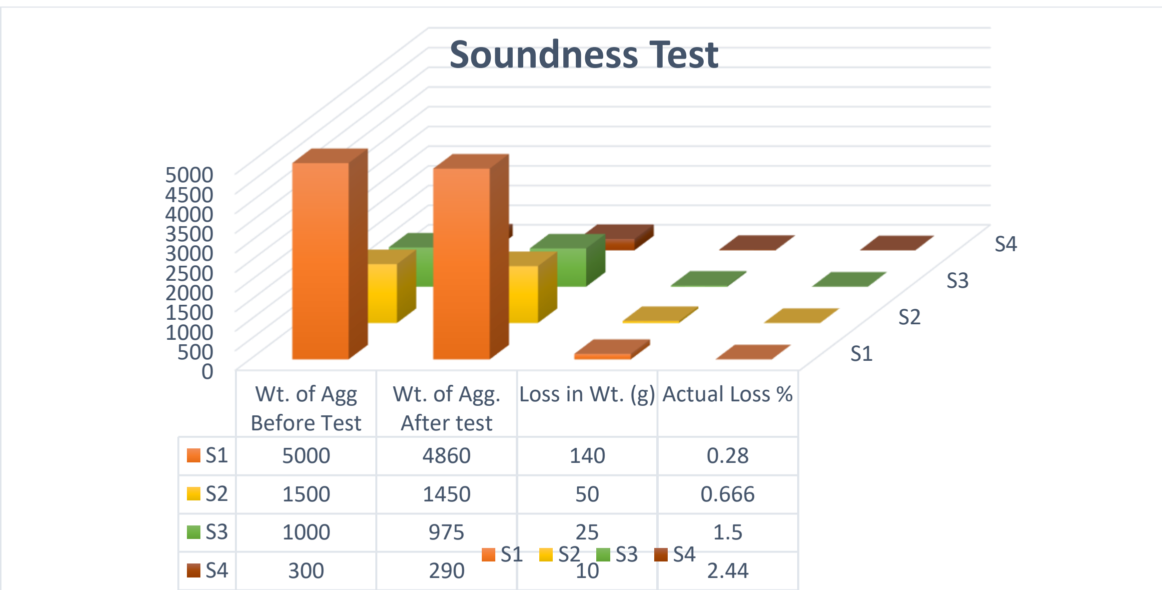


Figure 10. Graph showing the soundness test of different investigated sample.

4.3.9 Los angles abrasion test (ASTMC C-131)

According to NHA specifications, the Los Angeles Abrasion limit for coarse aggregate, specifically Class B, is set at 46%. The test conducted on the aggregate in this study yielded results within this acceptable range, indicating its suitability for use as construction material (Table 8).

Table 8. Los Angles abrasion test (ASTM C-131)

Sieve size		Weight of aggregate and classes			
Passing	Retained	A	B	C	D
1 1/2	1	1250±10			
1	¾	1250±10			
3/4	½	1250±10	2500±10		
1/2	3/8	1250±10	2500±10		
3/8	¼			2500±10	
1/4	No. 4			2500±10	
No.4	No.8				5000±10
Total wt. of sample, gm		5000±10	5000±10	5000±10	5000±10
Abrasive charges		13	11	8	6

$$\text{Los Angles Abrasion} = \frac{Total\ wt.of\ sample\ before\ test - wt.of\ sample\ after\ test}{Total\ wt.of\ sample} \times 100$$

$$\text{Los Angles Abrasion} = \frac{5000 - 4200}{5000} \times 100$$

Los Angles Abrasion = 26.8%

5. Conclusions

The petrographic and physico-mechanical properties of andesitic and granitic rocks from Ghizar district of Gilgit Baltistan, Pakistan, were investigated, draws the following conclusions. Petrographic examination reveals that the rock samples consist of primarily of essential minerals such as quartz, biotite, ore minerals, and hornblende, with minor amounts of celeste, epidote, muscovite, and plagioclase. Physio-mechanical analysis demonstrated favorable properties under the requirement imitates for construction materials: The Gradation value of 7.37 falls within may be specified limits, making it suitable for coarse aggregate. The Specific Gravity average of 2.966 meets requirements for coarse aggregates. The average Absorption % of 0.432 indicates not suitability for usage as coarse aggregate. The Porosity average of 2.948 falls within maybe acceptable limits. The combined Flakiness Index (7.5%), Elongation Index (4.85%), and average of 10.9% not meet specified criteria. The Soundness average result of 1.878% is within may be not specified limits. The Los Angeles Abrasion average result of 26.9% not meets requirements as per 40%. Based on the findings of this study, it is concluded that the andesitic and granitic rocks found in the study area exhibit properties suitable for construction purposes, particularly as dimension stone. However, these rocks are not suitable for use as coarse aggregate. Geologically, the study area is situated within the collisional zone between the Eurasian Plate and the Kohistan Island Arc. Rocks along this boundary have undergone significant deformation and metamorphism. As a result, the quartz content in these rocks is notably high, making them highly reactive. Therefore, due to their high silica content and reactivity, these rocks are not recommended for use as coarse aggregate but are suitable for applications where dimensional accuracy and aesthetic appeal are paramount, such as in dimension stone.

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