

## Petrographic and Physiomechanical Investigation of Late Cretaceous Kawagarh Formation Kahi Section, Nizampur Basin

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**Abstract:** The late Cretaceous Kawagarh Formation has been investigated in terms of field observation, and petrographic analysis, to understand the petrography and its impact on the geotechnical properties. The Kawagarh Formation is well exposed among the upper Indus Basin, and has been studied by various workers in different aspects. Kawagarh Formation exposed in Kahi section of Nizampur Basin has been selected in this study to know the behavior of carbonate rocks for engineering purposes. Lithologically, this formation is composed of thick to medium bedded, highly fractured limestone, marls, and dolomitic limestone which has undertaken diagenetic alteration including dolomite, calcite veins, and stylolites. Followed by petrographic analysis which reveals that the Kawagarh limestone is mostly fossiliferous comprised of a large number of planktonic foraminifera fossils like Globotruncana Hilli and Globotruncana Linneana fossils. Furthermore, to know the impact of petrographic minerals on engineering behavior, mechanical properties in terms of uniaxial compressive strength (UCS) and uniaxial tensile strength (UTS) were also computed by using a universal testing machine (UTM). The resultant mechanical values lie in the strong compressive strength and suggest their usage for various construction purposes. Aggregate degradation tests including water absorption, specific gravity, aggregate impact value, Los angles abrasion, and soundness was also computed according to the International standard organization, ASTM (American Society for testing materials) and British standard. The aggregate values of the Cretaceous Kawagarh Formation are within the defined standard limits and can be used as an aggregate source for different construction engineering projects.

**Keywords:** UTS, UCS, aggregate properties, petrographic analysis.

### Introduction

Rock as a construction material has been used for thousands of years. Correct prior knowledge of the ground conditions like, the mechanical and physical properties of rocks strata are very important for the use of engineering project construction like bridges, roads, tunnels, and dams. Universal compressive test (UCS) and universal tensile test (UTS) are two most important tests being extensively used to find out the mechanical properties of various rocks (Hawkes and Mellor, 1970). Although aggregate properties like loss angeles test, water absorption test, impact value test, specific gravity test, and soundness test are significant to use as aggregate source and dimension stones (Ngerebara and Youdeowei, 2014). Petrographic features are greatly influencing the mechanical properties of intact rocks. The physical properties of crushed rock aggregate are influenced by microstructures and mineral composition of rock and it was studied by many workers (Ramsay et al., 1974; Hartley, 1974; Lees Kennedy, 1975). Mineral constituents, bioclasts, cement, and texture are inversely related to the UCS of rock aggregate (Bell, 1978; Shakoor and Bonelli, 1991; Yates, 1992; Bell and Lindsay, 1999). UCS, UTS, mineralogical and textural characteristics of rocks are directly related to the physical properties of construction material. Therefore, the properties like evaluation of the soundness of

limestone aggregate sources are very important for the construction purpose. The aggregate potential of the Kawagarh Formation was determined through mechanical tests (UCS and UTS), aggregate tests, and correlates with the petrographic studies.

The Late Cretaceous carbonate strata are well exposed in Hazara and Nizampur basins. Lithologically this Formation comprises limestone, dolomitic limestone, marls, and dolomite. In the Hazara Basin, this formation has been analyzed by many researchers previously in terms of its sedimentological and paleontological aspects (Rahman et al., 2016; Khan et al., 2010; Rehman, 2009; Ahsan and Chaudhry, 2008). Most of the researchers investigated its depositional environment and the reservoir characterization, but there is a lack of study about the petrographic analysis and its relation with geotechnical properties. In the current research, the detailed field observation and petrographic investigations of Kawagarh Formation, exposed in the Kahi section of Nizampur Basin were conducted to deliver information about the mineralogy and its impact on geotechnical properties.

### Geology of study area

The research area is the part of the Nizampur Basin which lies in the vicinity of Kahi village. Geologically,

the study area is part of foothills of NW Himalaya fold & thrust belt. Nizampur Basin is bounded by Attock Cherat ranges in the north, Gandghar ranges in the NE side, Kala Chitta ranges in the south, and Kherimar hills

analysis includes Specific Gravity, Water absorption, Soundness, Los-Angeles Abrasion, and Impact Value tests.

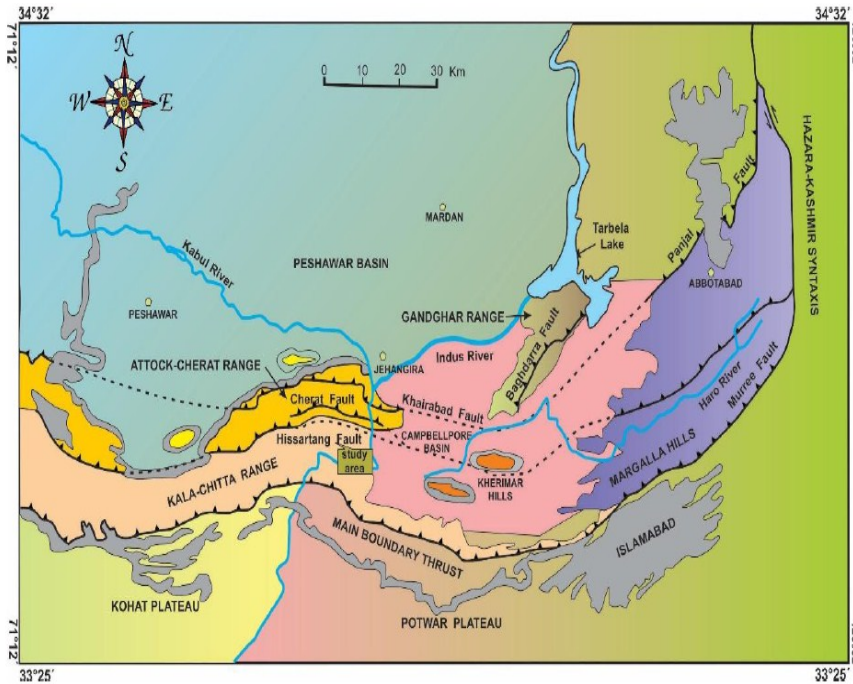


Fig. 1. Tectonic map of Hill ranges NW Pakistan (Modified after Yeats and Hussain, 1987). Inset showing study area.

the east (Burbank et al., 1989). Structurally, the area is bounded by two major faults: Hissartang thrust in the north and the Main Boundary thrust marks the southern boundary (Yeats and Hussain, 1987). The deformation is highly intense in the Kahi area due to the movements of these two major faults (Fig. 1) Most of the geological units in the study area are folded and thrust in nature. Stratigraphically, the study area hosts the Mesozoic and Cenozoic rocks, which comprise the Jurassic, Cretaceous, and Paleocene age formations. In the study area, these stratigraphic successions are thrust over each other, from the north towards the south, Jurassic rocks occur over the Cretaceous rocks, which are thrust over the Paleocene age rocks.

**Material and Methods**

Detailed field investigations of outcrop exposure of Kawagarh Formation in the Kahi Nala section were carried out. Ten representative samples were collected from the target outcrop for the physiomechanical properties. Out of these 10 samples, five were tested for mechanical characteristics and the remaining five were tested for the aggregate analysis. Moreover, 18 samples were examined under conventional microscopy (Olympus CX31 along with DP-21 camera attachment), for thin section analysis at the Department of Earth Sciences Quaid-e-Azam University Islamabad, Pakistan. The mechanical behavior was investigated through Unconfined Compressive Strength (UCS) and Unconfined Tensile Strength (UTS) while the aggregate

**Results and Discussion**

**Field observations**

An extensive geological field trip was conducted in the study area where the Kawagarh Formation was studied in detail. The Kawagarh Formation consists mainly of limestone, marls, and dolomitic limestone (Fig. 2A). In the field, limestone and dolomite show a sharp contact, and are differentiated through color contrast as the limestone displays light grey whereas, dolomite exhibits mostly dark grey color (Fig. 2B). Calcite veins and fracturing were also observed in the limestone (Fig. 2C). A late-stage stylolite also occurs that crosscuts the limestone (Fig. 2D).

**Petrography:**

The petrographic observation of the Cretaceous Kawagarh Formation reveals that the formation mostly comprises of the fossils assemblages. In previous studies, many workers reported diverse planktonic foraminifera from different localities (Ahsan and Chaudhry, 2008). In the current study, planktonic foraminifera including Globotruncana hilli (Fig. 3A) and Globotruncana linneana (Fig. 3B) were observed which are the preserved diagnostic fossils of the Cretaceous Kawagarh Formation. Based on petrographic studies, different diagenetic minerals were identified which include dolomites, calcites, and pyrite. Petrographic study also reveals that dolomitization also

took place in the Kawagarh Formation which exhibits euhedral crystal morphology (Fig. 3C). Calcite vein

Table 1. Uniaxial compressive strength (UCS) and Uniaxial tensile strength (UTS) values of the limestone of Cretaceous Kawagarh

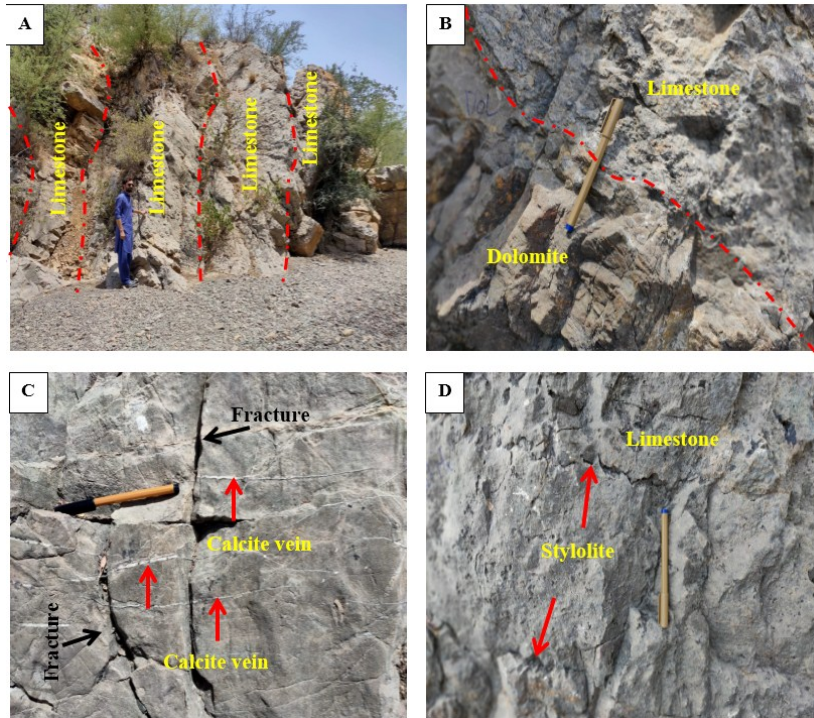


Fig. 2. Field photographs of Late Cretaceous Kawagarh Formation, Kahi section. (A) Outcrop view of thick-bedded limestone (B) Sharp contact between limestone and dolomite (C) White color vein filling calcite cement (red arrows) and fracturing (black arrows) in the limestone (D) Late-stage low angle bedding parallel stylolites crosscut the limestone.

passes from the dolomite and limestone parts and also crosscuts each other (Fig. 3C) which were recognized as a later stage diagenetic feature. Pyrite (Fig. 3C) and stylolite (Fig. 3D) were also recognized in the thin section analysis. The stylolite crosscuts the calcite vein (Fig. 3C) and marks as a postdate diagenetic phenomenon.

**Uniaxial Compressive Strength**

Unconfined Compression Test (UCS) is generally considered as the best and easiest method to determine the mechanical strength of rock (Zhou et al., 2020; Kou et al., 2019). UCS was performed on five samples from which the mean values of unconfined compressive strength were obtained. The UCS values for the Cretaceous Kawagarh Formation range between 67.08 and 98.01 MPa with a mean of 81.6 MPa (Table 1). The resultant values of UCS for these analyzed samples lie in the strong strength range of ISO (International standard organization, 2003) rock material classification (Table 2) for UCS (ISO 14689-1).

**Unconfined Tensile Strength (UTS)**

The unconfined tensile strength (UTS) values for rocks will be smaller than their unconfined compressive strength (UCS) values respectively (Bell, 2007). The obtained results of UTS for limestone of Cretaceous Kawagarh Formation range from 14.2 MPa to 19.2 MPa with a mean of 17.24 MPa Table 1.

Formation.

| Sample | Lithology | Rock Strength Test |           |
|--------|-----------|--------------------|-----------|
|        |           | UCS (MPa)          | UTS (MPa) |
| Kw 1   | Limestone | 81.8               | 14.2      |
| Kw 2   | Limestone | 78.4               | 17.8      |
| Kw 3   | Limestone | 67.8               | 18.4      |
| Kw 4   | Limestone | 81.9               | 19.2      |
| Kw 5   | Limestone | 98.1               | 16.6      |

**Aggregate Tests**

Various aggregate analyses were carried out on the limestone samples of the Cretaceous Kawagarh Formation. This aggregate degradation test includes Los Angeles Abrasion Value (LA AV), Soundness test, Aggregate Impact Value (AIV), Specific gravity (Sg), and Water Absorption (Wa) test. The aggregate competency depends upon the value of abrasions and will be higher where the abrasion value is minimum (Collis and Smith, 1993). The limestone results of LA AV for the Cretaceous Kawagarh Formation varies from 19.28% to 22.45% with an average value of 21.22 (Table 3) which is within the range of standard limits. The soundness test measures the resistance of aggregate against weathering and erosion which determines the aggregate degradation in different weathering environments (Mitchell, 2007). The results of the soundness test range from 1.88% to 2.54% with average values of 2.22 for the limestone of the Cretaceous Kawagarh Formation (Table 3). Aggregate Impact value determines the toughness and mechanical resistance in response to quick impact load (Fookes and



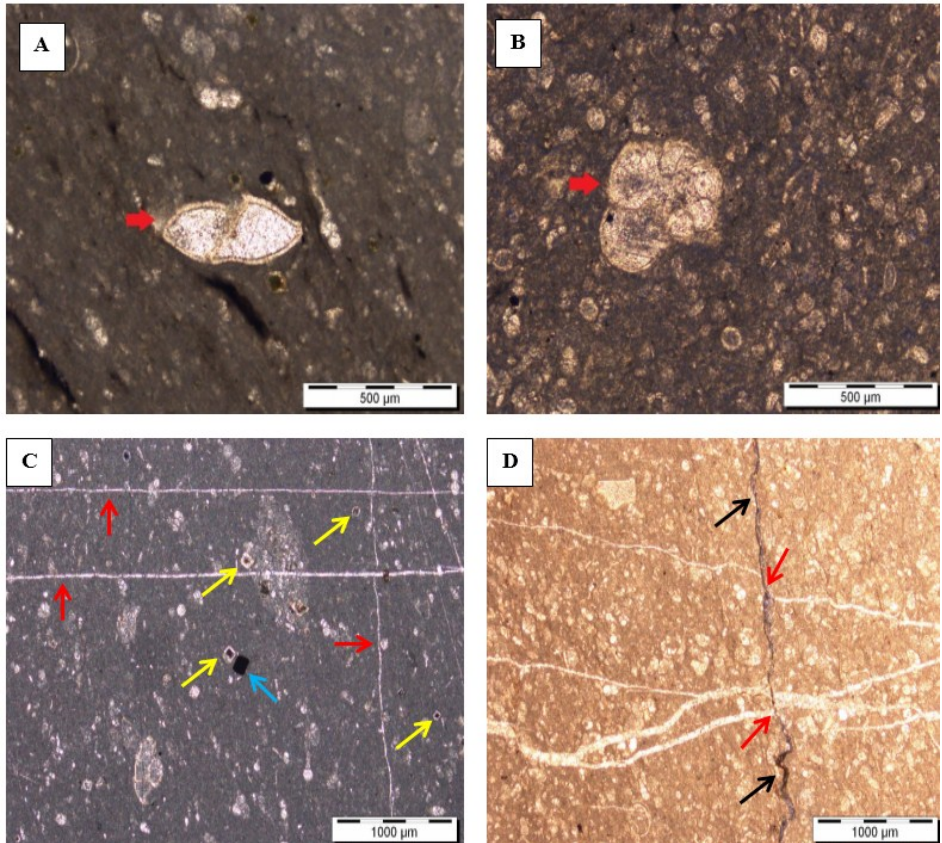


Fig. 3. Representative petrographic observations of limestone showing fossil records and different diagenetic features. (A) *Globotruncana hilli* (B) *Globotruncana linneana* (C) different episodes of calcite veins (red arrow), euhedral fine to medium-grained dolomite (yellow arrow), and Framboidal pyrite (blue arrow). (D) stylolite (black arrow) that crosscut the calcite veins (red arrow) and is recognized as a postdate diagenetic phenomenon.

Gourley, 1988). The AIV results of the limestone of the Cretaceous Kawagarh Formation vary from 13.44% to 15.87% with average values of 14.78 (Table 3). The obtained results lie within the range of best aggregate with an impact value of 10% to 20% (Standard, 812-112:19902013).

Table 2. Classification of rock material based on unconfined compressive strength (ISO 14689-1, 2003), where the current work classifies as a strong rock strength.

| Term for UCS     | Strength (Mpa) | Present work |
|------------------|----------------|--------------|
| Extremely weak   | <1             |              |
| Very weak        | 1-5            |              |
| Weak             | 5-25           |              |
| Medium-strong    | 25-50          |              |
| Strong           | 50-100         | ★ ★ ★        |
| Very strong      | 100-250        |              |
| Extremely strong | >250           |              |

Water absorption is the capability of rock to absorb water and can be related to the increased rock porosity (Lees and Kennedy, 1975). The specific gravity measures the aggregate resistance against compaction, which is controlled by its mineralogical pattern (Ahsan and Gondal, 2016). The results of specific gravity and water absorption for the Cretaceous Kawagarh Formation range from 2.64% to 2.71% and from 0.86% to 0.94% with average values of 2.68 and 0.90 respectively (Table 3).

The Cretaceous Kawagarh Formation in the Kahi Nala section of Nizampur Basin was investigated by field observations, petrography, mechanical and aggregate analysis. The field observation shows that the Kawagarh Formation consists of light grey limestone and dark grey dolomite along with minor marls. Diagenetic features like fracturing, calcite veins, stylolite, and occurrence of pyrite are also observed. The microscopic observation reveals that the major part of limestone is fossiliferous and contains diagenetic alteration. The identified fossils are planktonic foraminifera including *Globotruncana hilli* and *Globotruncana linneana* as major fossils. The veins and fractures are mostly filled by calcite and pyrite. Mechanical and aggregate analyses were also performed on the selected samples which include uniaxial compressive strength (UCS), uniaxial tensile strength (UTS), Los Angeles abrasion test, Soundness test, Aggregate impact value, Specific gravity, and Water absorption.

The physiomechanical results taken from the limestone of Cretaceous Kawagarh Formation were compared with the BS and ASTM standards for road and concrete aggregate in (Table 3). The selected limestone is fractured in nature which can increase water absorption proportionality, but the obtained results are within the ASTM 127 range which shows the incapability of water incorporation into limestone, and are unable to cause

Table 3 Mean Water absorption, Specific Gravity, Aggregate Impact value, Los Angeles abrasion and Soundness values of limestones from Cretaceous Kawagarh Formation along with ASTM and BS standard limits.

| Aggregate degradation tests    | Limestone Samples |       |       |       |       | Mean values | Standards (Limits) for aggregates                       |
|--------------------------------|-------------------|-------|-------|-------|-------|-------------|---|
|                                | Kw1               | Kw2   | Kw 3  | Kw 4  | Kw 5  |             |   |
| Water Absorption (%)           | 0.87              | 0.86  | 0.94  | 0.90  | 0.91  | 0.90        | ASTM 127 (Less than 2.5%)<br>For concrete aggregate     |
| Specific gravity               | 2.64              | 2.71  | 2.71  | 2.66  | 2.68  | 2.68        | ASTM 127 (min. 2.6)<br>For road and concrete aggregates |
| Aggregate impact value (%)     | 13.44             | 14.75 | 15.87 | 15.58 | 14.28 | 14.78       | BS 812:112 (max. 30%)<br>For cement Concrete            |
| Los Angeles abrasion value (%) | 22.18             | 19.28 | 20.41 | 21.78 | 22.45 | 21.22       | ASTM C-131 (less than 40%) For road aggregates          |
| Soundness (%)                  | 2.27              | 2.44  | 2.54  | 1.88  | 1.96  | 2.22        | ASTM C127 (max. 30%)                                    |

any destruction in terms of engineering behavior (ISRM, 1981). The UCS and UTS values fall within the strong strength and can be used in pavement and load building units (Goodman, 1980). Rocks, with water absorption values less than 1% by weight, can be considered as a building material because of the higher resistance to weathering (Blyth and De Freitas, 1974). Water absorption values of the Kawagarh Formation vary from 0.86 - 0.94% which are in the cement concrete range of ASTM-127 and mark limestone specifications for cement concrete. The specific gravity values range from 2.64 to 2.71 which almost comparable with ASTM 127 standard specification for cement concrete (Table 3). The results of soundness tests range from 1.88% to 2.54% following the range of ASTM C127 (Table 3) and showing negligible effect during intense environmental conditions. Aggregate impact value is considered the most important and standard test that measures the aggregate resistance against sudden shock and impact (Smith and Collis, 2001). The aggregate impact value of the Kawagarh Formation ranges from 13.44-15.87% which lies within limits of BS 812 for their application as aggregate in cement concrete (Table 3). Los Angeles abrasion measures the aggregate resistance toward abrasion and their durability increases with a decrease in its values. The obtained values of Los Angeles abrasion for the limestones of the Kawagarh Formation range between 19.28-23.45%, which are lower than the 40% as specified by ASTM C-131, and thus suitable for road aggregate purpose.

## Conclusion

Field observation reveals that major part of Kawagarh Formation comprises of the hard-compacted limestone along with dolomitic limestone as a minor portion in deformed nature. The occurrence of fractures in the limestone of Kawagarh Formation is due to the Kahi thrust that lies in the vicinity of the target region. Petrographic investigation shows that the limestone of this formation is fossiliferous which comprises the Planktonic foraminifers as a major component. Various diagenetic features like calcite veins, stylolite, and pyrite were also observed. Physiomechanical analysis revealed that UCS, UTS, along with aggregate results of Kawagarh Formation are within the range of the recommended ASTM standards and suitable for general

building and structural purposes and can also be used as a construction stone in various projects.

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