# GEOTECHNICAL ASSESSMENT OF CARBONATE ROCKS BASED ON TEXTURAL CHARACTERISTICS FROM THE UPPER INDUS BASIN, PAKISTAN

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## ABSTRACT

This study provides a comprehensive geotechnical assessment of carbonate rocks from the Upper Indus Basin, Pakistan, emphasizing the influence of textural and mineralogical characteristics on their physical, mechanical, and thermal properties. The analyzed carbonate rocks include limestones from the Wargal Limestone, Samana Suk Formation, Lockhart Limestone, Nammal Formation, and Sakesar Limestone, as well as dolostones from the Jutana and Kingriali Formations.

The petrographic analysis revealed distinct compositions and classifications among the limestone samples. The Wargal Limestone sample is characterized as a bioclastic grainstone, primarily composed of bioclasts within a sparite matrix. In contrast, the limestone from the Samana Suk Formation is classified as an ooidal grainstone, dominated by non-skeletal grains, mainly ooids, embedded in a sparite matrix. Another sample collected from the Samanasuk Formation is referred to as dedolomitized limestone, where dolomite has been replaced by calcite. The Lockhart Limestone sample is identified as a bioclastic packstone, consisting of bioclasts within a micrite matrix. The limestone from Nammal Formation, a neomorphosed mudstone, exhibited micrite transformation into microspar due to neomorphism. Similarly, the Sakesar Limestone sample is classified as a bioclastic wackestone, containing skeletal grains embedded in a micrite matrix. Furthermore, distinct characteristics were observed in dolostone samples. The dolostone from the Jutana Formation (D1) comprises fine- to medium-grained, subhedral dolomite crystals, whereas

the dolostone from the Kingriali Formation (D2) is distinguished by prominent secondary porosity resulting from diagenetic processes.

The examined rocks exhibit distinct variations in mechanical performance based on their mineralogical composition, texture, and diagenetic history. Micrite-dominated limestones generally exhibit superior strength due to their fine-grained, cohesive matrix, which enhances grain bonding and minimizes weak points. In contrast, sparite-dominated limestones exhibit lower strength, as their coarser sparite crystals create a less dense and more brittle structure with limited grain bonding. Similarly, diagenetic alterations, such as neomorphism and dedolomitization, increase porosity and weaken the structure, reducing mechanical strength. Dolostones display varying behaviors depending on their crystal morphology, porosity, and diagenetic history, with stronger dolostones characterized by interlocking crystal structure and minimal porosity, while weaker dolostones are associated with higher porosity due to diagenetic processes.

The texture coefficient (TC) method was employed to quantify rock microfabric and evaluate its influence on engineering properties.TC values ranged from 0.32 to 0.98, with higher values generally corresponding to greater grain content. Regression analysis revealed that the TC had limited predictive capability for the engineering properties of the studied carbonate rocks. Petrographic factors such as mineralogical composition, matrix type, and diagenetic features, which are not accounted for by TC, played a more significant role in determining the strength and durability of the studied rocks.

The carbonate rocks subjected to thermal treatment at 150°C, 300°C, 450°C, and 600°C exhibited significant changes in physical and mechanical properties, particularly beyond 300°C. Porosity and water absorption increased with rising temperatures, while specific gravity, UPV, SHT, UCS, and PLT values progressively declined due to microcrack formation and structural weakening. The degree of thermal degradation varied based on mineralogical composition and textural characteristics. These findings emphasize the importance of detailed geotechnical assessments to ensure the selection of durable and resilient carbonate rocks for engineering applications while mitigating potential risks associated with weaker rocks.