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Role of Engineering Geology in Mining Aggregate, Building Stone: A Case Study of Sangjani Taxila, Limestone, Islamabad, Pakistan

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Abstract: To meet the growing demand for sustainable construction materials, the identification of high-quality aggregate reserves based on geological and economic parameters is essential. This study investigates the physico-mechanical and petrographic characteristics of Eocene Margalla Hill Limestone from Sangjani–Taxila to evaluate its suitability as a source of construction aggregates. Field mapping, systematic sampling, and laboratory tests following AASHTO and ASTM standards demonstrate that the limestone exhibits excellent engineering properties, meets international performance criteria, and poses no risk of alkali–silica or alkali–carbonate reactions. With extensive outcrops, favorable accessibility, and consistent lithology, the Margalla Hill Limestone represents a significant sustainable resource for future civil and mining projects.

Keywords: ***Margalla hill limestone, Aggregate quality, Physico-mechanical properties, Concrete performance, Taxila Pakistan.***

Introduction

Rapid urbanization and infrastructure development worldwide have dramatically increased the demand for high-performance aggregates. In regions undergoing mega-development projects, such as the China–Pakistan Economic Corridor (CPEC), hydropower dams, expressways, and housing schemes, reliable sources of construction aggregates have become strategically important. Limestone is among the most widely used aggregate materials because of its durability, ease of processing, and widespread distribution, particularly in the Himalaya (Bell, 2007).

In this context, the identification of new aggregate reserves requires a systematic combination of engineering geology, petrography, and physico-mechanical testing. The present study aims to evaluate the potential of Margalla Hill Limestone of the Eocene age, exposed prominently in the Sangjani–Taxila region, as a sustainable source of high-quality construction aggregates. This research also contributes to optimising the performance of concrete and asphalt mixes while meeting global standards for sustainable building materials (ASTM, 2007).

Geological setting

The Margalla Hill Limestone is part of the Lesser Himalayan sedimentary sequence and is well exposed in the northern Punjab region. The formation comprises dark grey to pale grey marine limestone, interbedded with marl and shale. These lithologies represent deposition in a shallow marine environment during the Eocene, leading to the accumulation of fossiliferous, micritic limestones that are laterally extensive and structurally stable (Hassan et al., 2020).

The limestone is generally medium to thick-bedded, nodular in parts, and cut by frequent calcite veins. Marl beds are grey to brownish grey, compact, and hard, whereas shale beds are splintery, greenish grey to reddish-brown. The total thickness of the formation in the study area ranges from 60 to 90 meters, offering significant potential for long-term extraction.

Methodology

The study began with detailed geological mapping to understand lithological variations and structural characteristics. The outcrops were divided into three distinct zones, each representing slightly different proportions of limestone, marl, and shale. Representative samples were collected from each zone to ensure comprehensive assessment of the formation's engineering potential.

Nine representative limestone samples were tested in the Materials Testing Laboratory, Institute of Geology, University of the Punjab. The physico-mechanical tests followed ASTM and AASHTO standards and included:

- Los Angeles abrasion (LA: ASTM C131; ASTM D-2419-14)
- Aggregate Impact Value (AIV: AASHTO T85)
- Aggregate Crushing Value (ACV)
- Shape tests (flakiness and elongation indices: ASTM D-4791-10)

- Specific gravity and water absorption (AASHTO T85, 2001)
- Soundness tests
- Coating and stripping of bitumen

Complementary petrographic analysis was performed using thin sections to determine mineralogy, texture, fossil content, and the presence of potentially reactive silica or carbonate phases.

Physico-mechanical properties

The engineering tests reveal that the Margalla Hill Limestone exhibits mechanical properties within acceptable ranges for both national and international construction standards (Table 1):

Table 1, Engineering test values.

Properties	Values
Los Angeles Abrasion Value	23.76%
Aggregate Impact Value	16.79%
Aggregate Crushing Value	26.41%
Flakiness Index	10.57%
Elongation Index	10.97%
Specific Gravity	2.66
Water Absorption	0.76%
Soundness Test	1.55%
Coating and Stripping (Bitumen Affinity)	97.05%

These results demonstrate that the limestone is hard, durable, resistant to abrasion, and capable of withstanding mechanical stresses in concrete and asphalt applications. The low water absorption indicates minimal pore space, enhancing freeze–thaw durability and long-term performance.

Petrographic characteristics

Petrographic analysis identifies the rock as predominantly micritic limestone, composed of micritic calcite, minor sparitic calcite, clay minerals and hematite/limonite (opaque minerals). The groundmass contains abundant, well-preserved fossil assemblages including Assilina, Nummulites, Lockhartia, miliolites, and fragmented shells. Assilina constitutes approximately 40%, while Nummulites contribute up to 20%, confirming a shallow warm-marine depositional environment. Importantly, the petrographic analysis shows no significant quantities of reactive silica, indicating very low risk of alkali–silica reaction (ASR). Similarly, the mineralogy of the carbonate phases suggests no susceptibility to alkali–carbonate reaction (ACR)—a crucial criterion for durable concrete aggregates (ASTM C568-03).

Economic and engineering significance

The Margalla Hill Limestone is widely exposed, laterally continuous, and easily accessible due to major highways and urban centers such as Islamabad and Taxila. Its substantial thickness ensures long-term availability, making it ideal for sustained aggregate production.

Given the surge in infrastructure projects, particularly CPEC motorways, hydropower projects, industrial zones, and urban expansion, the demand for durable aggregates will continue to rise. The high quality of Margalla Limestone makes it an economically viable and environmentally sustainable choice for future civil and mining projects.

Conclusion

This study confirms that Margalla Hill Limestone possesses the necessary physico-mechanical and petrographic attributes to serve as an excellent source of construction aggregates. All engineering properties meet or exceed ASTM and AASHTO limits, and petrographic evaluation shows no risk of harmful chemical reactions. Its large areal extent, accessibility, and favorable lithological characteristics make it a strategic aggregate reserve capable of supporting national-scale infrastructure development. As sustainable construction gains global importance, high-quality limestone deposits such as those in the Margalla Hills will play a vital role in ensuring reliable and long-lasting building materials.

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