Afghan International Journal of Science (AIJS)
Publisher: Afghan International Islamic University
Website: https://aijs.aiiu.edu.af
e-ISSN: 3134-5859

The Development of High-Performance Concrete Using Afghanistan's Mineral-Rich Aggregates for Strategic Infrastructure: A Review

Naweed Ahmad Rabani[1*], Abdulhai Kaiwaan[2], Abdullah Namdar [3]

[1&2] Afghan International Islamic University (AIIU), Department of Structural Engineering, Faculty of Engineering, Kabul, Afghanistan
[3]Abu Dhabi University, Faculty of Engineering, Abu Dhabi, United Arab Emirates

Abstract

Infrastructure development depends on high-performance concrete (HPC), particularly in Afghanistan, where growing building needs necessitate long-lasting, environmentally friendly materials. With its compressive capabilities, HPC can enhance strength, durability, and environmental resilience by utilizing natural additives, such as zeolite and calcite, in conjunction with Afghanistan's abundant mineral-rich aggregates, including quartzite, basalt, and limestone. Despite the abundance of these local resources, little is known about how they might be in HPC. This study reviews the literature to explore it and evaluates cost, sustainability, and reduced reliance on imports by contrasting their features with HPC criteria. Afghanistan's mineral potential is contextualized through case studies from geologically similar countries. The study provides theoretical and comparative insights to promote resilient infrastructure by synthesizing research on mechanical characteristics, resilience to environmental stresses, and sustainability. The finding indicates that while additives like zeolite promote hydration and self-healing, lowering ecological impact, local aggregates increase strength and longevity. This strategy could help Afghanistan's industrial revolution and long-term infrastructure viability by reducing costs and emissions and promoting economic growth. The study closes gaps in the use of Afghanistan's mineral wealth to support sustainable HPC growth by offering practical ideas for researchers, construction specialists, and politicians.

Keywords: High-performance Concrete (HPC), Mineral-Rich Aggregates, Natural Mineral Additives, Sustainable Infrastructure, Strategic Infrastructure Development

Article History

Published: June 30, 2026
Accepted: May 17, 2026
Revised: Feb 16, 2026
Received: Dec 11, 2025

Cite as: Rabani, N. A., Kaiwaan, A., Namdar. (2026). The Development of High-Performance Concrete Using Afghanistan's Mineral-Rich Aggregates for Strategic Infrastructure: A Review. *Afghan International Journal of Science 2*(2), 212-226. DOI: https://doi.org/10.66546/aijs.v2i2.17

Introduction

Strategic infrastructure refers to the essential physical infrastructure and facilities that play a critical role in a nation's functioning, security, and socio-economic development. Typically, these infrastructures include the transportation infrastructure, such as roads, bridges, and airports, the energy infrastructure, including electricity generation and distribution, water

[*]Email: naweedrabani890@gmail.com (Corresponding Author)
Link to the article: https://aijs.aiiu.edu.af/index.php/aijs/article/view/17

supply and sanitation infrastructure, and the essential public facilities, including hospitals and communication infrastructure. It is believed to play a fundamental role in improving the economy, connectivity, and the ability to counter environmental and geopolitical challenges (Organization for Economic Cooperation and Development, 2007). Moreover, it is widely believed to be the backbone for sustainable development, particularly in developing nations where the absence of infrastructure directly impacts the economy (World Bank, 2020). It is worth noting that the importance of infrastructure in Afghanistan is much greater than in other nations, given the requirements for developing infrastructure materials that can withstand environmental challenges. Hence, the development of high-performance concrete using the readily available mineral-rich aggregates can play a significant role in the improvement of the infrastructure.

Afghanistan's vital infrastructure, which includes highways, military installations, and industrial complexes, requires cutting-edge building materials to endure harsh operational and climatic conditions. These applications require high-performance concrete (HPC), which is defined by compressive strength of more than 55MPa, remarkable durability, and improved workability (American Concrete Institute, 2018; Kosmatka et al., 2016). The quality of HPC's aggregates and additives, which influence mechanical strength, hydration, and resilience, determines how well it performs (Mehta & Monteiro, 2014; Kepeluszna et al.,2021). Afghanistan has a great deal of potential for HPC production because of its diverse geology, which includes natural additives like zeolite and calcite as well as plentiful mineral-rich aggregates, including quartzites, basalt, and limestone (Sharifi et al.,2020; USGS, 2014). According to the Afghanistan Geological Survey (2021), these resources lessen dependency on pricy imports and promote the development of sustainable infrastructure. Using thorough literature-based research, this study assesses the viability of using Afghanistan's quartzite, basalt, limestone aggregates, and natural mineral additives in HPC for important infrastructure. It evaluates the economic and sustainability benefits in the context of Afghanistan while reviewing the body of research on their performance in terms of strength, durability, workability, and environmental resistance. The goal is to inform best practices for Afghanistan's infrastructure development by using case studies on previously studied mineral-rich aggregates and natural additives. To suggest the combined use of local aggregates and additives in HPC manufacturing, this entails combining the results of pertinent literature. Afghanistan's aggregates meet HPC requirement: limestone improves workability, basalt increases durability under sulfate exposure (Li et al., 2018; Wang et al., 2020), and quartzite increases compressive strength (Kasi et al., 2019). However, ASR risks must be managed ("Alkali-Aggregate Reactivity (AAR) Potential of Selected Canadian Aggregates For Use in Offshore Concrete Structures," 1994; Bhatty, 1985). Zeolite and other additives boost strength to 58.5 MPa while lessening their negative effects on the environment (Kapeluszna et al., 2021; Larsen et al., 2022). In line with global sustainability targets (United Nations Environment Program, 2020; International Energy Agency, 2021), locally produced resources reduce prices and emissions while promoting economic growth through the creation of jobs (World Bank, 2022; USGS, 2014). This strategy might alleviate Afghanistan's 70% unpaved road shortfall and revolutionize the country's building industry (Sorensen, 2020). This study fills a gap in the use of Afghanistan's mineral resources, aggregates, and additives for HPC by providing A literature-based framework to improve the resilience of infrastructure. It attempts to offer practical ideas for sustainable development by including case studies from places like Pakistan and Iraq. Philippines, Ukraine ... (Abdulrahman et al., 2023; Mukhammadiev & Malikov, 2025), assisting Afghanistan's environmental objectives and economic recovery. This study fills a gap in the use of Afghanistan's mineral resources, aggregates, and additives for HPC by providing a literature-based framework to improve the resilience of infrastructure. It attempts to offer practical ideas for sustainable development by including case studies from places like Iran and Pakistan (Hakeem et al., 2022; Mukhammadiev & Malikov, 2025), assisting Afghanistan's environmental objectives and economic recovery.

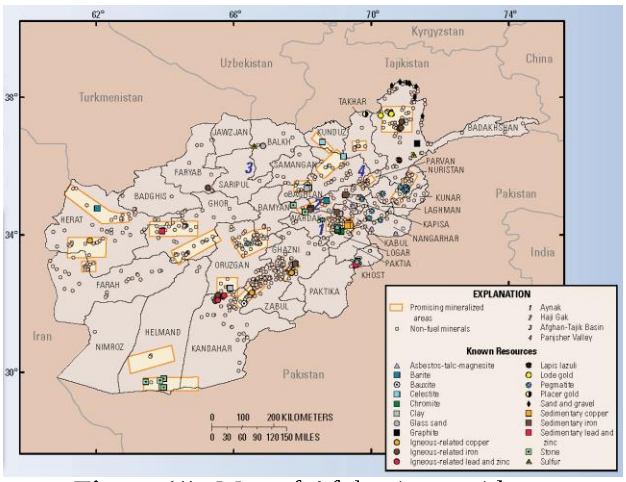


Figure (1): Map of Afghanistan with Mineralized Areas, USGS

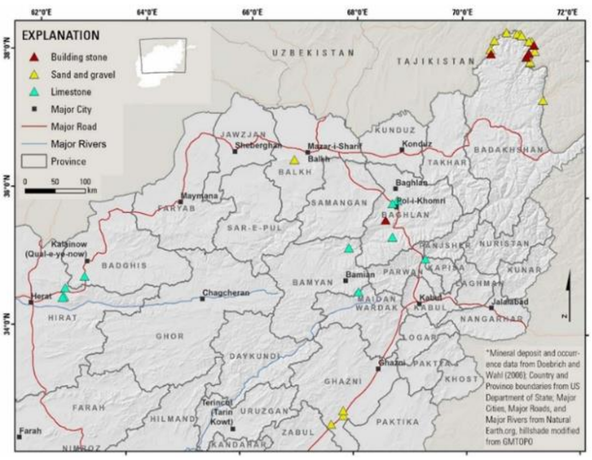


Figure (2): Afghanistan Country profile by World Bank, EGPS and USGS, 2021.

The literature review section examines previous studies on the characteristics of aggregates and natural mineral additives that affect high-performance concrete (HPC), with a focus on the abundant minerals of quartzite, basalt, and limestone in Afghanistan, as well as additives like zeolite and calcite, to evaluate their potential for strategic infrastructure like highway/ roads, bridges, and military installations. Highlighting mechanical characteristics, durability, and sustainability implications pertinent to HPC in Afghanistan, the paper summarizes a thorough literature survey.

High-performance concrete (HPC) is ideal for demanding infrastructure applications due to its remarkable workability, durability, and compressive strength (> 55 MPa) (American Concrete Institute, 2018). Achieving these qualities requires the use of aggregates and additives, which account for 60-70% of concrete volume and improve its hydration, strength, and resilience (Mehta & Monteiro, 2014). Research indicates that HPC performance is influenced by the size, strength, and interfacial bonding of the aggregate, especially at low water-cement ratios (w/c < 0.4), where the quality of the coarse aggregate is crucial (Teymen, 2023; Wu et al., 2001). By increasing C-S-H formation by 35%, additives such as natural zeolite can raise strength to 58.5 MPa (Kapeluszna et al., 20210). Utilizing local aggregates and minerals could help alleviate infrastructure deficiencies in Afghanistan, where 70% of roads remain unpaved (Sorensen, 2020), while reducing reliance on imports (Sharifi et al., 2020). The metamorphic rock quartzite, which contains 95-99% silica, is a strong HPC aggregate due to its high hardness (Mohs 7) and low water absorption (<1%) (Mehta & Monteiro, 2014). Because of its mechanical strength and bonding at low w/c ratios, Wu et al.

(2001) found that crushed quartzite had higher compressive and tensile strength than marble or limestone. While Bhavya and Sanjeev (2017) observed that 12mm quartzite achieved maximal strength throughout M20-M30 grades. Abdullahi (2012) discovered that quartzite outperformed river gravel. According to Kumar and Bhattacharjee (2003), quartz improves rigidity and energy absorption, making it perfect for bridges. Although abrasiveness poses processing difficulties, its use could increase HPC durability in Afghanistan's quartzite-rich region (USGS, 2014; Mehta & Monteiro, 2014). In Afghanistan, basalt is a common igneous rock (Peters et al., 2011). Its high density (2.9-3.3 g/cm3) and strength (up to 300MPa) improve HPC durability (Li et al., 2018). While Mekonen et al. (2024) observed that dense aggregates (such as steel slag) enhance strength by 15.8%, a pattern relevant to basalt, Konitufe and Baba (2023) found that angular aggregates, such as basalt, increase strength up to 14 mm in size, outperforming rounder ones. Afghanistan's highway requirements are met by its low permeability (Wang et al., 2020), while increased weight would necessitate design changes (Kosmatka et al., 2016). The sedimentary basins of Afghanistan host limestone with smooth particles and a high calcium carbonate content (>90% CaCO3), which improves HPC workability (Farny & Kosmaka, 2020). While Wu et al. (2001) observed lower strength than quartzite, Ismail (2023) found that limestone's low porosity yields greater compressive strength and absorption resistance than marlstone. According to Kumar and Bhattacharjee (2003), calcite helps precast parts become more ductile. Although ASR risk must be reduced ("Alkali-Aggregate Reactivity (AAR) Potential of Selected Canadian Aggregates For Use in Offshore Concrete Structures," 1994), Afghanistan's sustainable HPC is supported by its abundance. Aggregate is complemented by natural minerals such as calcite, trass, and zeolite, which improve HPC characteristics. While Alfaqawi et al. (2022) observed self-healing with bacteria, Kapeluszna et al. (2021) found that zeolite reduced Ca(OH)2 by 23% and increased C-S-H by 35%, reaching 58.5 MPa. According to Gowram and M (2022), the ideal ratio for durability was 5% zeolite and 10% metakaolin. 15% volcanic rock powder densifies mortar (Tang et al., 2024), while 5% wollastonite boosts strength to 57.8 MPa (Karpikov et al., 2020). By using local minerals, these additions reduce their environmental impacts (Larsen et al., 2022), supporting Afghanistan's sustainability objective (USGS, 2014). Environmental factors that affect HPC durability include temperature, humidity, and chemical exposure. While Gong et al. (2022) observed that salinity promotes corrosion in coastal areas, lowering load capacity, Chaabi et al. (n.d.) discovered that higher temperatures decrease elastic modulus (Blikharskyy et al., 2021). For Afghanistan's diverse environment, these impacts are minimized by ideal w/c ratios and additives such as corrosion inhibitors (Castañeda Valdés et al., 2024). Resilience is improved by aggregates such as basalt and additives such as zeolite, which promote long-term infrastructure performance. Case studies from a similar region inform Afghanistan's HPC potential. In Iraq, Abdulrahman et al. (2023) show that larger aggregates increase shear strength, which is pertinent to the utilization of basalt. In the Philippines, Basaran et al. (2022) found that crushed aggregates perform better than natural aggregates, bolstering the use of basalt and quartzite. With 10-20 mm aggregates, Development of High-Performance Concrete Mixtures for Durable Bridge Decks in Montana Using Locally Available Materials," 2005, in Indonesia, obtained 36.1 MPa, indicating size optimization for Afghan materials. These illustrations demonstrate long-lasting, reasonably priced HPC that uses indigenous resources, lowering Afghanistan's reliance on imports (Afghanistan Ministry of Mines and Petroleum, 2019). The literature emphasizes that limestone, quartzite, and basalt can all satisfy the HPC requirement when supplemented with zeolite and calcite. While additives enhance hydration and resilience, quartzite increases strength (10-20%), basalt durability, and limestone workability (Kapeluszna et al., 2021; Wu et al., 2001). Mix design can be used to overcome issues with abrasiveness, weight, and ASR (Teymen, 2023). According to these findings, Afghanistan may use its mineral wealth, such as dolomite and quartz, to boost economic growth, promote sustainability, and improve infrastructure resilience through local sourcing (USGS, 2014; Sharifi et al., 2020).

Methods and Materials

Research Design

This study uses a literature-based research design to evaluate the viability of using natural mineral additives like zeolite and calcite in conjunction with Afghanistan's mineral-rich aggregates, such as quartzite, basalt, and limestone, to produce high-performance concrete (HPC) for strategic infrastructure, such as military bases, bridges, and highways. The method evaluates aggregate and additive properties, HPC performance, and environmental sustainability impacts by synthesizing peer-reviewed studies, a geological report, and regional case studies without conducting new experiments. This approach supports the goal of using existing research to inform best practices for Afghanistan.

Data Collection

Data on the characteristics of quartzite, basalt, and limestone aggregates, natural mineral additions, and their uses in HPC were obtained through a systematic literature review of reliable sources. Keywords such as high-performance concrete, quartzite aggregates, basalt aggregates, limestone aggregates, natural zeolite in concrete, concrete additives, compressive strength, durability, environmental impacts on concrete, and Afghanistan mineral resources were used to search academic databases such as Science Direct, Google Scholar, Elsevier Link, and Springer Link.

Selection Criteria

Physical and chemical characteristics, HPC performance indicators, environmental impacts, and sustainability results were all covered in the included studies. Non-peer-reviewed and non-English publications were not included. The U.S. Geological Survey (USGS, 2014) and the Afghanistan Geological Survey (Sharifi et al., 2020) provided the geological data.

Key Sources

For aggregates, Chandra and Ramaraju (2022) provided quartzite strength data (53.2N/mm2), Li et al. (2018) basalt durability, and Farny and Kosmatka (2020) limestone workability. Additives were reported by Kapeluszna et al. (2021) for zeolite (58.5 MPa) and by Karpikov et al. (2020) for wollastonite (57.8 MPa). Environmental insights were drawn from Chaabi et al. (n.d.) and Gong et al. (2022).

Data Types

Extracted data included aggregate/additive characteristics, concrete performance, economic/environmental benefits, and regional applications.

Data Analysis

Data were analyzed using a comparative and interpretive approach. Aggregate and Additives Properties were compared to the HPC standard. Performance Impact was quantified in terms of effects on strength, durability, and workability. The Environmental and Sustainability Context assesses resilience in Afghanistan's context and the benefits of local sourcing, drawing on case studies. Findings were validated across sources, with limitations noted due to reliance on secondary data.

Findings

Performance of Quartzite in HPC

Quartzite, abundant in Afghanistan (Sharifi et al., 2020), improves HPC. angular shape, minimal water absorption (<1%), Mohs hardness of 7, and high silica concentration (95-99% SiO_2) (Mehta & Monteiro, 2014). Chandra and Ramaraju (2022) found that a 20% substitution results in a compressive strength of 53.2 N/mm2, with a 10% reduction to 48.8 N/mm^2. According to Patial and Sharma (2023), replacing dust increases tensile strength by 32% and improves durability, even under exposure to acid and seawater (Chandra & Ramarju, 2022). According to Tolmachov (2023), tiny particles improve microstructural integrity. weathered varieties (reddish/yellowish) decrease workability and strength (Hassan et al., 2023), and abrasiveness wears equipment (Mehta & Monteiro, 2014), perfect for strong constructions such as military installations and Bridges (Chandra & Ramaraju, 2022).

Figure (3): Coarse aggregates of Limestone, Quartzite and Granite (Tufail et al, 2016).

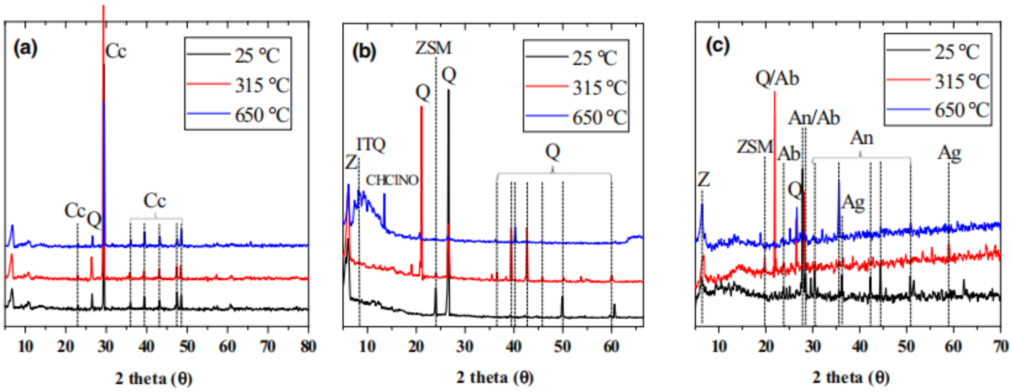
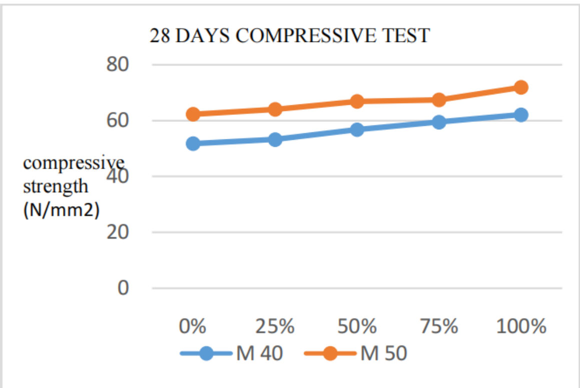


Figure (4): XRD pattern of mineral components in (a) limestone, (b) quartzite, and (c) granite aggregates (Notes: Cc calcite, Q quartz, Z Zeolite, ITQ calcined ITQ-4 (Si24O48), ZSM ZSM-23 (Si24O48), Ab albite, An anorthite, Ag augite) (Tufail et al, 2016).

Basalt's Performance in HPC

Basalt, abundant in Afghanistan's igneous regions (Peters et al., 2011), supports strong HPC. Low permeability, strength up to 300MPa, and high density (2.9-3.3 g/cm^3) (Li et al., 2018). Boosts durability against sulfate and freeze-thaw cycles and increases compressive strength by 10-20% (Li et al; Wang et al., 2020). Angularity causes increased weight and difficulties with workability (Kosmatka et al., 2016). Fits bridge decks and roadways under challenging conditions (Ahmed et al., 2016).



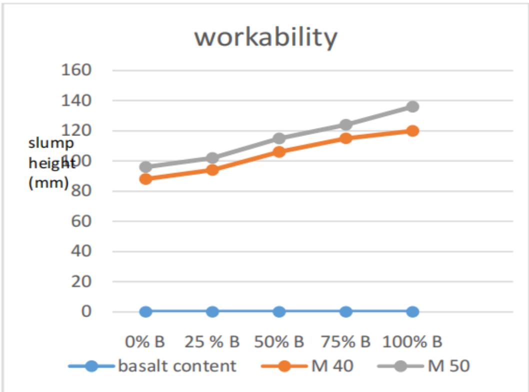


Figure (6): Concrete slump with Basalt Aggregate (Ikkurthi et al, 2015).

Figure (5): 28 days Concrete Compressive Strength with Basalt Aggregate (Ikkurthi et al, 2015).

Limestone's role in HPC

Limestone, found in Afghanistan's sedimentary basins, contributes to HPC's adaptability. Mohs hardness 3-4, smooth shape, high Ca CO_3 (>90%) (Bhatty, 1985). Enhances workability, lowers shrinkage, and provides carbonation-based self-healing (Bhatty, 1985). Weaker than quartzite/basalt; ASR risk if reactive silica is present ("Alkali-Aggregate Reactivity (AAR) Potential of Selected Canadian Aggregates For Use in Offshore Concrete Structures," 1994). Compatible with low-maintenance structures/constructions and precast elements (Bhatty, 1985).

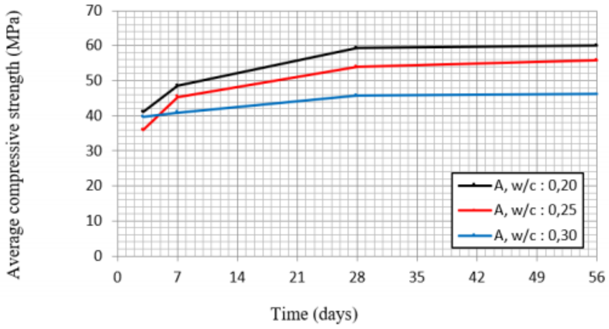


Figure (7): Compressive strength for natural sand as fine aggregate and limestone split as coarse aggregate (Tanijaya et al. 2021)

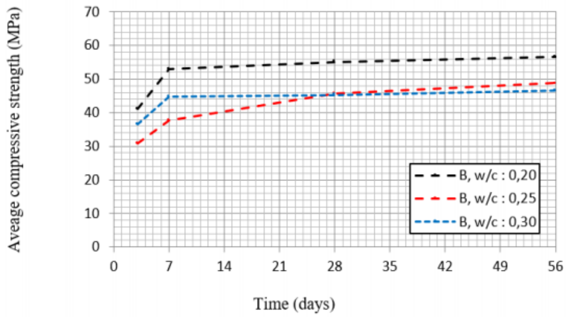


Figure (8): Compressive strength for limestone powder as fine aggregate and limestone split as coarse aggregate (Tanijaya et al. 2021)

Natural Mineral Additives' Performance in HPC

Afghanistan-sourced zeolite and calcite (USGS,2014) are examples of additives that improve HPC. Five percent wollastonite produces 57.8MPA (Karpikov et al., 2020); calcite enhances ductility (Kumar & Bhattacharjee, 2003); zeolite increases strength to 58.5 MPa and raises C-S-H by 35% (Kapeluszna et al., 2021). Excess may not improve attributes; ideal amounts (5-15%) are crucial (Subhash, 2022). Durable, self-healing structures (Akhtar et al., 2022).

Sustainability and the Environmental Repercussions

Local aggregate and additives have the potential to create jobs while lowering costs and emissions by up to 30% (Ahmed et al., 2016; Larsen et al., 2022). The elastic modulus decreases with temperature (Chaabi et al., n.d.), necessitating the use of additives, such as zeolite, to increase robustness (Gong et al., 2022). Environmental management and initial processing investment are obstacles.

Lessons from Regional Insights

Afghanistan can achieve cost-effective HPC using local materials and additives, thereby improving sustainability, according to Tolmachov's (2023) insights on quartzite from Ukraine and Iraq's aggregate-size optimization (Abdulrahman et al., 2023), and Pakistan's use of basalt in durable mixes (Ahmed et al., 2016).

Lesson from Regional Insights

Afghanistan can achieve cost-effective HPC using local materials and additives, thereby improving sustainability, as demonstrated by Tolmachov's (2023) quartzite from Ukraine, Iraq's aggregate-size optimization (Abdulrahman et al., 2023), and Pakistan's use of basalt in durable mixes (Ahmed et al., 2016).

Table 1: *Properties and Effects of Aggregates in HPC*

Aggregate	Key Properties	Effect on HPC	Potential Issues	Application in HPC	Source
Quartzite	High silica (95-99%), Hard (Mohs 7), Low absorption (<1%)	+10% strength at 20% replacement (53.2 N/mm²), Enhanced durability	Abrasiveness, Weathered variants reduce workability	Bridges, Military bases	(Chandra & Ramaraju, 2022; Hassan et al., 2023)
Basalt	Dense (2.9-3.3 g/cm³), Strong (300 MPa), Low permeability	+10-20% strength, High durability	Weight, Workability	Highways, Bridge decks	(Li et al., 2018; Wang et al., 2020)
Limestone	High $CaCO_3$ (>90%), Smooth, Workable	Improves workability, Self-healing	ASR risk, Lower strength	Precast, Low-maintenance structures	(Bhatty, 1985; "Alkali-Aggregate Reactivity (AAR) Potential of Selected Canadian Aggregates For Use in Offshore Concrete Structures," 1994)
Zeolite	Pozzolanic	+58.5 MPa, 35% C-S-H	Optimal dosing	Durable structures	(Kapeluszna et al., 2021)

Discussion

The results of this research offer compelling proof that Afghanistan's mineral-rich aggregates and natural additives have the potential for being effectively used in the production of high-performance concrete (HPC) for strategic infrastructure development; however, for such materials to be effectively used, a nuanced appreciation of the interaction of materials and conditions is required. Instead of treating these materials as distinct materials, the results of this research offer a compelling case for considering them as a multi-scale material system, in which micro-scale material behavior dictates macro-scale material performance.

At the microstructural level, the high silica content in quartzite rock (ranging from 95% to 99% SiO2) has been shown to increase the interfacial transition zone (ITZ) bond strength due to its chemical stability and minimal absorption, thereby improving compressive strength. However, there are trade-offs. The literature shows that high aggregate content can induce stress concentrations in the ITZ, leading to brittle failure in high-performance concretes (HPCs) with very low water-to-cement ratios (w/c < 0.35). Thus, there is a major limitation in the use of quartzite rock: although it has the highest strength, it can reduce ductility, a major factor in the performance of structures subjected to dynamic loads, such as those in Afghanistan. Thus, there is a need to balance absorption and strength, rather than pursuing maximum strength.

On the contrary, basalt is known for its high performance in harsh environmental conditions such as those containing sulfates and those subjected to freeze-thaw cycles. The high density of basalt minimizes permeability, which in turn reduces the penetration of ions. However, the high density of basalt (2.9-3.3g/cm^3) also leads to a penalty in terms of an increased dead load, which may not be desirable for long-span bridges. Therefore, a design paradox is created wherein materials that improve durability also have a negative effect on structure. Hence, basalt should be used in those cases where durability is a greater factor than weight efficiency.

Limestone plays a special role in concrete aggregates, which is more rheological than strengthening. The smoother surface and chemical composition of limestone improve workability and minimize shrinkage. This is especially important for large-scale concrete construction in hot climates. However, the relatively low hardness and possible ASR of limestone are drawbacks that may affect durability, especially if combined with reactive silica. This is a clear case of the need for chemical compatibility analysis in selecting aggregates, which is not considered in resource-based material utilization approaches. The results of the research showed that the best use of limestone is in blended aggregates, where it overcomes workability problems of stronger and harsher aggregates such as quartzite and basalt.

The use of natural mineral additives, such as zeolite, represents a breakthrough in the improvement of performance and sustainability. The increase in the formation of calcium silicate hydrate (C-S-H) by up to 35% has already validated the reactivity of zeolite, confirming its potential in refining pore structures. However, from a thermodynamic and kinetic perspective, the use of these additives is heavily dependent on the curing conditions, particle size, and proportion of replacement. Overuse of these additives can lead to a reduction in the performance of the cementitious system. Thus, the proportion of use of these additives does not have a linear relationship.

From a systems point of view, the study points out an important shift in construction practices based on imports to resource-based engineering design. Although the economic and environmental benefits of utilizing local resources in construction are substantial, as evident from reduced transportation emissions and cost savings, there are important challenges to this shift. Afghanistan lacks standardized material characterization and quality control, which are important in ensuring consistency in HPC production.

In addition, as compared with regional case studies such as Iraq, Pakistan, and Ukraine, the above observations confirm that geological similarity is not the only factor that guarantees favorable material performance; rather, processing methods, mix design methods, and construction methods are equally important. For example, the improved performance of crushed aggregates compared with natural aggregates in the Philippines suggests that Afghanistan must invest in aggregate processing technologies to make the best use of its available mineral resources.

Thus, in summary, the research findings suggest that there is potential for high-performance computing (HPC) production in Afghanistan, but there is a lack of materials to support this potential. Moving towards high-performance, sustainable infrastructure development in Afghanistan requires a framework that integrates materials science, structural design, environmental adaptation, and institutional development. The research contributes to the existing literature on HPC development uniquely by proposing a resource-based approach, while also highlighting the need for experimental validation, standardization, and policy support in this regard.

Recommendation

In order to improve durability, sustainability, and cost-effectiveness, validated through pilot projects and reinforced by cooperation and knowledge sharing, it is recommended that high-performance concrete (HPC) be developed and implemented in Afghanistan by optimizing mix designs for locally available aggregates, incorporating locally available natural mineral additives, enforcing strict quality control, and prioritizing local sourcing.

Conclusion

This research, based on a comprehensive literature review, shows that in Afghanistan, aggregates rich in minerals such as quartzite, basalt, and limestone can effectively produce high-performance concrete (HPC) when combined with natural additives such as zeolite and calcite. The results show that aggregates such as quartzite improve compressive strength, basalt improves durability in extreme environments, and limestone improves workability. In contrast, natural additives such as zeolite enhance hydration, increase C-S-H content, and impart self-healing capacity to concrete.

The results provide further support for the idea that using available materials can significantly reduce dependence on imports, construction costs, and carbon emissions, thereby promoting sustainable development. The comparative results from geologically similar areas provide further support for the technical viability of the approach.

However, the challenges posed by aggregate abrasiveness, the potential for alkali-silica reaction, and the lack of standardized testing methods must be addressed through optimized mix design and quality control measures.

Acknowledgements

It is the proper section in the paper to thank all the people who helped you most in carrying out your research work. For example, a supervisor, a sponsoring institution, a funding body, and your colleagues or other researchers who have helped in the preparation and agreed to share with you their unpublished results. Acknowledging people's help and contribution will ensure the integrity of your research. It is also worth remembering that the acknowledgment should be written in a professional manner, so try to avoid any emotional or personal thoughts.

Author Contributions

- Naweed Ahmad Rabani conceived and designed the study; conducted the literature review; performed data collection, experimental work, analysis, and interpretation of results; prepared figures and tables; wrote the original manuscript draft; and revised and finalized the manuscript.

- Abdulhai Kaiwaan provided academic supervision and guidance on the overall structure and organization of the manuscript and contributed to manuscript refinement and improvement.
- Abdullah Namdar contributed to the development and refinement of the research title; assisted in identifying relevant literature and references for the review section; and provided technical comments and suggestions.
- All authors reviewed the final version of the manuscript and approved it for publication.

References

Abdulrahman, H., Ahmed, M., & Ali, S. (2023). Influence of aggregate source and size on the shear behavior of high-strength reinforced concrete deep beams: Experimental. *Journal of Structural Engineering*, 149(4), 04023012. https://doi.org/10.1016/j.cscm.2023.e02260

Abdullahi, M. (2012). Effect of aggregate type on compressive strength of concrete. *International Journal of Civil and Structural Engineering*, 2(3), 791-800. https://doi.org/10.6088/ijcser.00202030008

Afghanistan Ministry of Mines and Petroleum. (2019). *Annual report on mineral resources and development*. Kabul: Government of Afghanistan. Link

Alfaqawi, R. M., Fareed, A., Zaidi, S. B. A., Airey, G. D., & Rahim, A. (2022). Effect of hydrated lime and other mineral fillers on stiffening and oxidative ageing in bitumen mastic. *Construction and Building Materials, 315*, 125789. https://doi.org/10.1016/j.conbuildmat.2021.125789

American Concrete Institute. (2018). *ACI 211.4R-08: Guide for selecting proportions for high-strength concrete using Portland cement and other cementitious materials*. ACI.

Alkali-Aggregate Reactivity (AAR) Potential of Selected Canadian Aggregates For Use in Offshore Concrete Structures. (1994). SP-145: Durability of Concrete -- Proceedings Third CANMET - ACI International Conference, Nice, France 1994. SP-145: Durability of Concrete -- Proceedings Third CANMET - ACI International Conference, Nice, France 1994. https://doi.org/10.14359/4562

Basaran, B., Kalkan, I., Aksoylu, C., Özkılıç, Y. O., & Sabri, M. M. S. (2022). Effects of Waste Powder, Fine and Coarse Marble Aggregates on Concrete Compressive Strength. *Sustainability, 14*(21), 14388. https://doi.org/10.3390/su142114388

Bhavya, S., & Sanjeev, K. (2017). Effect of different types of coarse aggregates on physical properties of mostly used grades M20, M25, M30 of concrete. *Construction and Building Materials*, 154, 1123-1130. https://doi.org/10.9790/1684-1401024651

Bhatty, M. (1985). Mechanism of Pozzolanic Reactions and Control of Alkali-Aggregate Expansion. *Cement, Concrete, and Aggregates*, *7*(2), 69–77. https://doi.org/10.1520/CCA10372J

Ca añeda Valdés, A., Corvo Pérez, F., Pech Pech, I., Marrero Águila, R., & Bastidas-Arteaga, E. (2024). Durability Requirements for Reinforced Concrete Structures Placed in a

Hostile Tropical Coastal Environment. *Buildings*, *14*(8), 2494. https://doi.org/10.3390/buildings14082494

Chaabi, A., Belarbi, R., & El-Sayed, M. (n.d.). Effect of temperature and humidity on concrete creep and shrinkage. *Journal of Materials in Civil Engineering*. https://doi.org/10.14359/6085 .

Chandra, N. V., & Ramaraju, K. (2022). Experimental study on properties of concrete by replacing coarse aggregate with quartzite. *International Journal for Science Technology and Engineering*, *10*(3), 369–379. https://doi.org/10.22214/ijraset.2022.40617

Development of High-Performance Concrete Mixtures for Durable Bridge Decks in Montana Using Locally Available Materials. (2005). SP-228: 7th Intl Symposium on the Utilization of High-Strength/High-Performance Concrete. SP-228: 7th Intl Symposium on the Utilization of High-Strength/High-Performance Concrete. https://doi.org/10.14359/14510

Gowram, I., & M, B. (2022). Experimental and analytical study of high-strength concrete containing natural zeolite and additives. *Civil Engineering Journal, 8*(10), 2318–2335. https://doi.org/10.28991/CEJ-2022-08-10-019

Hakeem, I. Y., Althoey, F., & Hosen, A. (2022). Mechanical and durability performance of ultra-high-performance concrete incorporating SCMs. *Construction and Building Materials, 359*, 129430. https://doi.org/10.1016/j.conbuildmat.2022.129430

International Energy Agency. (2021). *Net zero by 2050: A roadmap for the global energy sector*. IEA. Link

Ismail, N. R. (2023). A comparative study of the effect of aggregate type on the strength and abrasion resistance of concrete, Kurdistan Region, Iraq: Experimental. *Polytechnic Journal*, *13*(2). https://doi.org/10.59341/2707-7799.1722

Ikkurthi, S. K., Mounika, L., Prasad, C. M., & Krishna, B. H. (2015). Experimental study on the use of basalt aggregate in concrete mixes. *SSRG International Journal of Civil Engineering*, *2(*4), 1–5. https://doi.org/10.14445/23488352/IJCE-V2I4P107

Kapeluszna, E., Kotwica, L., & Nocuń-Wczelik, W. (2021). Comparison of the effect of ground waste, expanded perlite, and silica fume on the hydration of cements with various tricalcium aluminate content – Comprehensive analysis. https://doi.org/10.1016/j.conbuildmat.2021.124434

Li, P. P., Yu, Q. L., & Brouwers, H. J. H. (2018). Effect of coarse basalt aggregates on the properties of Ultra-high Performance Concrete (UHPC). *Construction and Building Materials, 170*, 649–659. https://doi.org/10.1016/j.conbuildmat.2018.03.109

Mukhammadiev, N., & Malikov, G. (2025). *Use of basalt fiber in concrete mixture for manufacture of prefabricated concrete and reinforced concrete structures*. 030043. https://doi.org/10.1063/5.0266812

Konitufe, C., Abubakar, A., & Baba, A. S. (2023). Influence of aggregate size and shape on the compressive strength of concrete. *CONSTRUCTION*, *3*(1), 15–22. https://doi.org/10.15282/construction.v3i1.9075

Kosmatka, S. H., Wilson, M. L., & Farny, J. A. (2016). *Design and control of concrete mixtures* (16th ed.). Portland Cement Association. https://doi.org/10.5479/sil.352050.39088006456024

Kumar, R., & Bhattacharjee, B. (2003). Porosity, pore size distribution and in situ strength of concrete, *Cement and Concrete Research.* https://doi.org/10.1016/S0008-8846(02)00942-0

Mehta, P. K., & Monteiro, P. J. M. (2014). *Concrete: Microstructure, properties, and materials* (4th ed.). McGraw-Hill Education. https://doi.org/10.1093/ae/36.1.56a

Mekonen, T. B., Alene, T. E., Alem, Y. A., & Nebiyu, W. M. (2024). Influence of Steel Slag as a Partial Replacement of Aggregate on the Performance of Reinforced Concrete Beam. *International Journal of Concrete Structures and Materials, 18*(1), 56. https://doi.org/10.1186/s40069-024-00698-5

Nasim, M., & Rao, A. K. (2024). Enhancing concrete properties through the strategic incorporation of granite and marble dust as sustainable alternatives to natural sand. *Journal of Physics: Conference Series*, *2779*(1), Article 012085. https://doi.org/10.1088/1742-6596/2779/1/012085

Neville, A. M. (2011). *Properties of concrete* (5th ed.). Pearson. https://doi.org/10.1061/(asce)cf.1943-5509.0000595

Patial, S., & Sharma, P. (2023). *Utilization of quartzite dust powder and marble dustpowder in concrete.* 020053. https://doi.org/10.1063/5.0120015

Organisation for Economic Cooperation and Development (OECD). (2007). Infrastructure to 2030: Main findings and policy recommendations. *OECD Publishing.* https://doi.org/10.1007/springerreference_75881

Peters, S. G., King, T. V. V., Mack, T. J., & Chornack, M. P. (2011). Mineral resources in Afghanistan: Summary of activities by the U.S. Geological Survey and Afghanistan Geological Survey, 2004–2011. *U.S. Geological Survey Open-File Report*, 2011-1204. https://doi.org/10.2113/econgeo.107.7.1515-b

Sharifi, Y., Houshiar, M., & Aghebati, B. (2020). An overview of Afghanistan's mineral resources and their potential for industrial development. Resources Policy, 67, Article 101673. https://doi.org/10.1016/j.resourpol.2020.101673

Sorensen, P. (2020). Infrastructure challenges in Afghanistan: A sectoral analysis. *Journal of Infrastructure Development*, 12(1), 45-60.

Tufail, M., Shahzada, K., Gencturk, B., & Wei, J. (2017). Effect of elevated temperature on mechanical properties of limestone, quartzite and granite concrete. *International Journal of Concrete Structures and Materials*, *11*(1), 17–28. https://doi.org/10.1007/s40069-016-0175-2

Tanijaya, J., Tappi, S., & Jabair. (2021). The mechanical properties of limestone as an aggregate on high strength concrete. *IOP Conference Series: Materials Science and Engineering*, *1088*(1), Article 012098. https://doi.org/10.1088/1757-899X/1088/1/012098

Teymen, A. (2023). Statistical investigation of the effects of different origin aggregate properties on the mechanical properties of concrete: Experimental. *Materials Science and Engineering*, 128(6), 064012. https://doi.org/10.7764/rdlc.22.2.482

Tolmachov, S. (2023). Concrete on quartzite aggregates. *Theory and Building Practice*. https://doi.org/10.23939/jtbp2023.02.093

United Nations Environment Programme. (2020). *Building sector emissions hit a record high, but a low-carbon pandemic recovery can help transform the sector*. UNEP. https://doi.org/10.18356/94e7342b-en

United States Geological Survey. (2014). *Mineral resources of Afghanistan*. USGS Publications Warehouse. Link

Wang, L., Zhang, Y., & Yang, S. (2020). Mechanical properties of basalt fiber-reinforced concrete under sulfate attack. *Materials and Structures*, 53(4), 1-12. https://doi.org/10.1016/j.jobe.2026.115968

World Bank. (2022). *Afghanistan economic update: Recovery remains fragile*. World Bank Group. World Bank. (2020). *Infrastructure for development*. World Bank Group. Link

Wu, K.-R., Chen, B., Yao, W., & Zhang, D. (2001). Effect of coarse aggregate type on mechanical properties of high-performance concrete. *Cement and Concrete Research*, *31*(10), 1421-1425. https://doi.org/10.1016/s0008-8846(01)00588-9