Smart Green Materials

POPULAR SCIENTIST

Research Article

Experimental Investigation on the Effect of Sand Type and Fineness Modulus on the Compressive Strength of Cement Mortar

Imon Hasan Bhuiyan, Abdul Awol Rabby, Abhijit Nath Abhi

Department of Civil Engineering, Faculty of Science, Dhaka Internaational University, Dhaka-1212, Bangladesh

***Corresponding Author:** Imon Hasan Bhuiyan (imonhasan5@gmail.com)

Articles History: Received: 1 October 2025; **Revised:** 16 October 2025; **Accepted:** 27 Oktober 2025; **Published:** 7 November 2025

Abstract

Compressive strength is considered one of the key parameters of mortar for ensuring the structural integrity and durability of masonry construction. Sand, as the primary fine aggregate in mortar, plays a crucial role in determining its mechanical properties. This study investigates the influence of sand type and fineness on the compressive strength of cement mortar cubes prepared with locally available sands in Bangladesh. Three types of sand Sylhet sand, Domar sand, and Local sand were selected for the experimental program due to their common use in construction projects. Two cement-to-sand ratios (1:4 and 1:6) were used to prepare a total of 48 mortar cubes (50 mm × 50 mm), which were cured in water for 3, 7, 14, and 28 days. The fineness modulus (FM) of the sands was determined according to ASTM C136-01, yielding values of 2.53, 2.29, and 1.72 for Sylhet, Domar, and Local sand, respectively. The compressive strength was measured using a Universal Testing Machine (UTM), and the average strength for each curing period was recorded. Results showed that Sylhet sand consistently produced the highest compressive strength across all curing ages, reaching approximately 32 MPa and 29.6 MPa at 28 days for the 1:4 and 1:6 mixes, respectively. Domar sand yielded moderate strength values for both the 1:4 and 1:6 mixes, while Local sand exhibited the lowest performance due to its coarser gradation and higher impurity content. Mixtures of two sands (particularly Sylhet and Domar) exhibited synergistic effects, resulting in improved strength compared to single-sand mortars. Additionally, strength gain from 7 to 28 days was significant, with 28-day strengths approximately 60% higher on average, demonstrating the importance of proper curing. The findings confirm that sand type and grading are critical factors influencing strength development in mortar, and they provide guidance for optimizing sand selection to achieve superior mortar performance in construction practice.

Keywords: Compressive Strength, Cement Mortar, Sand Type, Curing Period, Fineness Modulus

Introduction

Mortar is one of the most widely used construction materials, serving as a bonding medium in masonry and as a surface finish in plastering works [1]. Its performance is largely determined by its compressive strength, a critical parameter for ensuring the structural integrity and service life of masonry structures [2]. Its compressive strength is a key performance indicator that affects the structural integrity of masonry units. Factors affecting the strength of mortar are the cohesion of the cement paste and its adhesion to the aggregate properties [3]. Since masonry walls are predominantly subjected to compressive loads, the compressive strength of mortar is often considered the most important design property for ensuring adequate structural safety [4]. Recent studies have increasingly focused on sustainable and alternative fine aggregates. Wang et al. optimized green mortar using graded ferrochrome slag and dune sand, reporting enhanced performance through aggregate gradation [5]. Bader and Irshidat demonstrated that recycled sand from excavation wastes can achieve comparable strength while reducing environmental impact [6]. Skocek et al. investigated recycled aggregate concrete and showed that controlling particle size and absorption is crucial for performance [7]. Chafika et al. further highlighted that particle shape and cleanliness affect both workability and strength [8]. The strength of mortar depends on several factors, including the cement-to-sand ratio, the water-to-cement ratio, the type and grading of sand, and the curing conditions [9]. Among these, the properties of sand such as particle size distribution, shape, mineral composition, and cleanliness play a particularly significant role. Sand not only acts as a filler but also affects workability, water demand, and ultimately the strength of hardened mortar [10]. Sands with appropriate gradation and higher quartz content typically provide better packing density, reduce voids, and contribute to higher strength development [11]. Conversely, poorly graded or highly impure sands can reduce bonding efficiency between cement paste and aggregate, leading to lower strength and durability [12]. Previous research has shown that fineness modulus (FM) of sand directly correlates with compressive strength of mortar [13]. Well-graded sands with a balanced proportion of fine and coarse particles improve packing and reduce water demand, which results in denser and stronger mortar [14].

Despite extensive research internationally, there remains a gap in regional studies comparing local Bangladeshi sands, which differ in texture, mineral composition, and fineness. This study provides the first systematic evaluation of Sylhet, Domar, and Local sands to determine how their fineness and blending affect compressive strength. The paper also introduces a practical sand-blending optimization concept that can improve mortar quality using existing local resources. This research contributes to sustainable construction practices by promoting optimal use of locally available materials and reducing dependence on imported fine aggregates.In Bangladesh, Local sand (LS), Domar sand (DS), and Sylhet sand (SS) are among the most widely used fine aggregates for mortar production. However, their physical characteristics differ significantly: Sylhet sand is typically well-graded and relatively clean, Domar sand is moderately graded, and Local sand often contains impurities and has coarser gradation. Despite their widespread use, there has been limited systematic research comparing their effect on compressive strength of cement mortar under controlled conditions.Mortar specimens were prepared using three types of sand (Local, Domar, and Sylhet) and tested at four curing periods (3, 7, 14, and 28 days) for two mix ratios (1:4 and 1:6).

https://doi.org/10.70028/sgm.v2i2.62

The present work addresses the gap in performance data for locally sourced sands in Bangladesh by experimentally evaluating their influence on compressive strength and proposing a practical blending strategy. The study aims to quantify how fineness and gradation affect strength development and to provide actionable data for sustainable mortar formulation.

Materials

Cement

Ordinary Portland Cement (OPC), meeting the standards of ASTM C150 and BSTI (Bangladesh Standards and Testing Institution) specifications, was used throughout the experimental program. OPC is the most widely used cement in construction due to its high early strength development and good binding properties [15]. The cement used was fresh, free from lumps, and stored in dry conditions to avoid exposure to moisture.

The main physical and chemical characteristics of OPC that make it suitable for mortar preparation include its specific gravity (approximately 3.15), fineness and adequate initial and final setting times [16]. Since mortar strength strongly depends on cement quality, only a single batch of cement was used to maintain consistency across all mixes.

Sand (Fine Aggregate)

Sand was the main variable investigated in this study, as its grading, shape, and mineral composition significantly influence the compressive strength of mortar. Three different types of sand commonly used in Bangladesh were selected.

- Sylhet Sand (SS): A well-graded, relatively clean natural river sand with FM = 2.53. Due to its higher quartz content and favorable grading, it is known to produce strong mortar mixes.
- Domar Sand (DS): Moderately graded sand with FM = 2.29. Its performance was expected to fall between Sylhet and local sands.
- Local Sand (LS): A lower-quality sand (FM = 1.72) containing finer particles and impurities such as silt and clay, which can reduce bonding with cement paste.

The fineness modulus (FM) of each sand was determined by sieve analysis following ASTM C136 [17]. Results confirmed that Sylhet sand was best graded, while local sand exhibited poor gradation and higher fines content.

Water

Clean potable water, free from organic matter, oils, and salts, was used for both mixing and curing. Water quality is critical in cementitious materials since impurities (such as chlorides and sulfates) can interfere with hydration [18].

https://doi.org/10.70028/sgm.v2i2.62

Methodology

Research Design

The experimental program was designed to evaluate the effect of different sand types and mix proportions on the compressive strength of cement mortar. The study followed a controlled laboratory testing approach in which only one variable (sand type or mix ratio) was altered at a time, while other factors such as cement, water quality, and curing conditions were kept constant. This approach ensured that differences in results could be directly attributed to the properties of sand.

Collection of Materials

- Sand: Three types of sand (Sylhet, Domar, and local) were collected from construction supply sources in Bangladesh (Figure 1). Representative samples were taken following the procedure outlined in ASTM D75 (Standard Practice for Sampling Aggregates).
- Cement: Ordinary Portland Cement (OPC) was used for all mixes.
- Water: Clean potable water was used for mixing and curing.

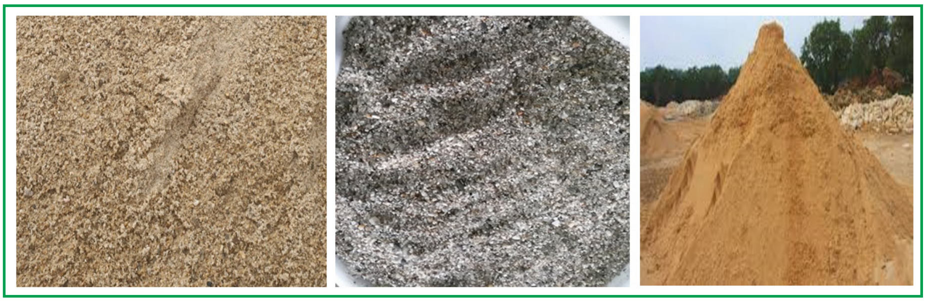

Figure 1. Three types of sand (from right to left Sylhet, Domar and local sand

Sieve Analysis and Fineness Modulus

The particle size distribution of each sand sample was identified through sieve analysis following the guidelines of ASTM C136 [19]. The fineness modulus (FM) was calculated to assess the coarseness or fineness of the sand, which is a key factor influencing packing density and mortar strength. Previous studies have confirmed that FM strongly affects compressive strength development [20].

Mix Proportions

Two cement-to-sand ratios were adopted: 1:4 and 1:6 by weight. These represent commonly used mortar mixes in masonry (1:4) and plastering (1:6) applications [21]. The 1:4 ratio generally yields higher compressive strength, whereas the 1:6 ratio represents a more economical mix with moderate strength.

In addition to single-sand mixes, combinations of two sands in equal proportions (Sylhet+ Domar, Sylhet+ Local, Domar+ Local) were tested. Blended sands often provide improved particle packing and reduced voids, leading to denser and stronger mortar [22]. A constant water–cement ratio of 0.50 was maintained across all mixes.

https://doi.org/10.70028/sgm.v2i2.62

Specimen Preparation

Mortar specimens were prepared as 50 mm × 50 mm × 50 mm cubes using steel molds, following ASTM C109 (Standard Test Method for Compressive Strength of Hydraulic Cement Mortars) as can be seen in Figure 2. The procedure was as follows:

- Batching and Mixing: Cement and sand were weighed according to the specified mix ratios. Dry mixing was performed until a uniform blend was achieved. Water was then added gradually, and the mixture was stirred manually until a workable, homogenous mortar was obtained.
- Casting: Fresh mortar was poured into lubricated steel cube molds in two layers, with each layer compacted using a tamping rod to eliminate air voids.
- Finishing: The top surface was leveled using a trowel. The molds were covered with a damp cloth for 24 hours to prevent moisture loss.

Figure 2. Specimen of cement mortar cube

Curing of Specimens

After demolding, specimens were submerged in clean water at room temperature until the day of testing (3, 7, 14, and 28 days) as in Figure 3. Proper curing is essential to maintain adequate moisture for hydration, which directly influences strength development. The curing process was carried out according to ASTM C511 (Standard Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks used in the Testing of Hydraulic Cements and Concretes).

Figure 3. Curing of the mortar specimen

Compressive Strength Testing

After each curing period, the mortar cubes were tested for compressive strength using a 2000 kN capacity Universal Testing Machine (UTM), in accordance with ASTM C109 guidelines (Figure 4). The load was applied at a controlled pace until failure, and the peak load was documented. Compressive strength (MPa) was determined by dividing the recorded maximum load by the cube's loaded surface area. For each mix and curing age, three specimens were tested, and the average strength was reported to minimize random errors.

Figure 4. Compressive strength testing under UTM

Data Analysis

The results were analyzed by comparing the compressive strength across different sand types, mix ratios, and curing ages. The trends were interpreted in light of the sand gradation, fineness modulus, and literature findings. Previous studies on mortar and concrete strength development were consulted to validate experimental outcomes.

Results and Discussion

Fineness Modulus and Sand Characteristics

The sieve analysis confirmed that the fineness modulus (FM) of Sylhet, Domar, and local sand was 2.53, 2.29, and 1.72, respectively. According to ASTM classifications, Sylhet sand falls within the medium-fine range, Domar sand is slightly finer, and Local sand is excessively fine.

The gradation curve of Sylhet in Figure 5. sand demonstrates a well-graded distribution typical of medium-fine river sands. This favorable particle spread contributes to improved packing density and reduced void content, which enhance mortar strength. The higher FM of Sylhet sand suggests better gradation and quartz content, explaining its superior performance in later tests.

https://doi.org/10.70028/sgm.v2i2.62

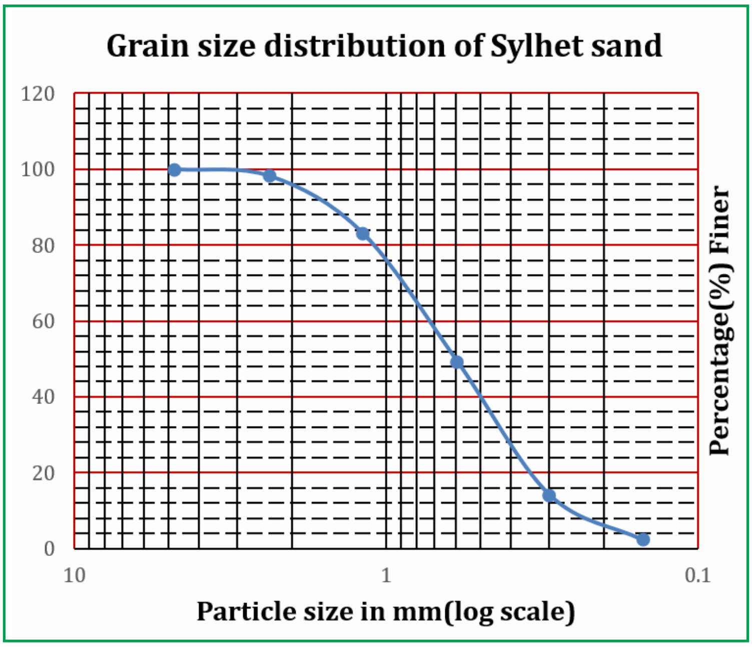

Figure 5. Gradation curve of Sylhet sand

The gradation curve of Domar sand in Figure 6. shows a slightly finer distribution with fewer coarser particles compared to Sylhet sand. While still adequate for mortar production, this narrower range can slightly increase water demand and marginally reduce density.

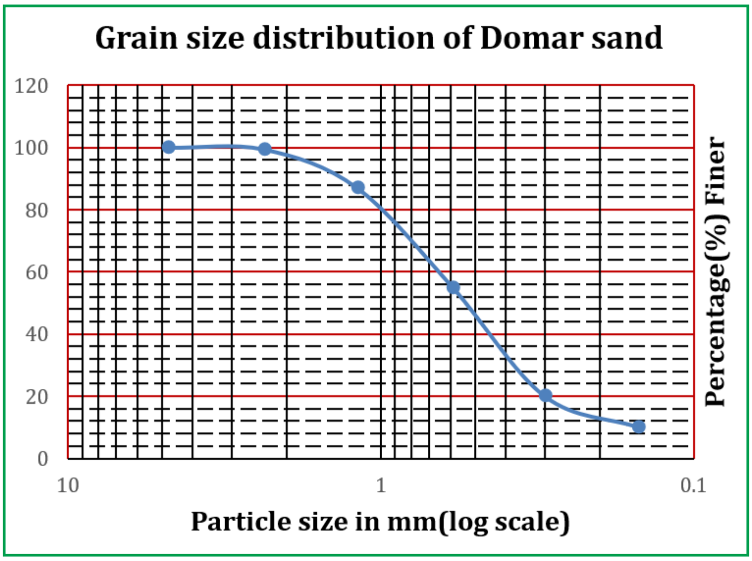

Figure 6. Gradation curve of Domar sand

The gradation curve of local sand in Figure 7. displays a predominance of very fine particles, confirming its low fineness modulus (1.72). The curve indicates excessive fines that may increase water requirement and weaken the bond between cement paste and aggregate.

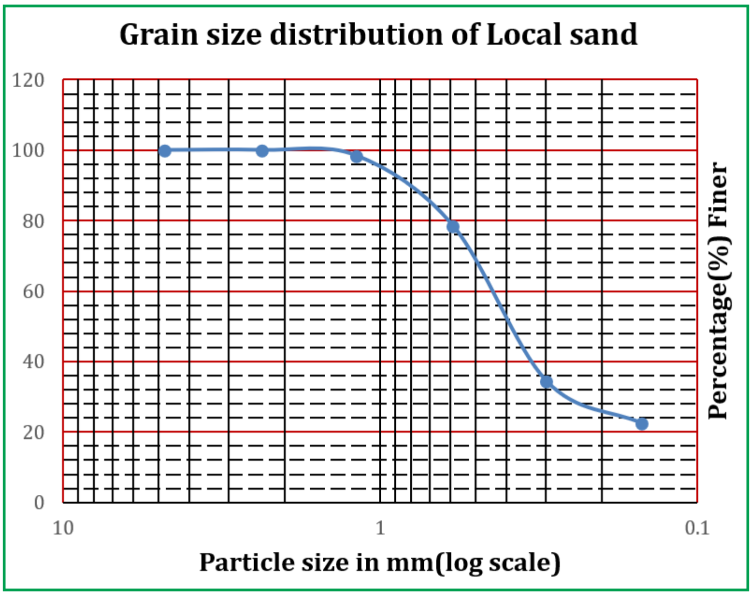

Figure 7. Gradation curve of local sand

Compressive Strength at Different Mix Ratios

The compressive strength results demonstrate a consistent ranking of sands across both ratios (Table 1).

Table 1. Compressive strength of cement mortar of different types of sand (cement to sand mix ratio 1:4 and 1:6)

	Cement to Sand mix ratio 1:4				**Cement to Sand mix ratio 1:6**			
Mixing Composition	Average compressive strength (MPa) for different curing days				Average compressive strength (MPa) for different curing days			
	3 days	7 days	14 days	28 days	3 days	7 days	14 days	28 days
OPC + SS	9.86	18	26	32	8.8	16	24	29.6
OPC + DS	8.26	14	20	26	6.27	12	20	24.4
OPC + LS	5.6	8	12.4	20.8	4	6.8	10	17.6

Figures 8 and 9 present the compressive strength evolution for mortars with 1:4 and 1:6 cement-to-sand ratios, respectively. Sylhet sand produced the highest compressive strength at all ages. For the 1:4 mix, the 28-day strength reached ~32 MPa, which is about 22% higher than Domar sand and 54% higher than local sand and for the 1:6 mix, Sylhet sand achieved 21% higher strength than Domar sand and 68% higher than local sand at 28 days.

Domar Sand displayed intermediate performance (28 days curing strength for 1:4 mix ratio is 26 MPa and 24.4 MPa for 1:6 mix ratio), with strengths moderately lower than Sylhet sand but significantly higher than local sand (Table 2). Local sand consistently yielded the lowest compressive strength, with a 28-day strength of ~20 MPa in the 1:4 mix and ~17MPa in the 1:6 mix. The weak performance is attributed to poor gradation and higher presence of deleterious materials. These findings align with earlier studies that emphasized the importance of sand gradation and mineral purity in achieving high compressive strength.

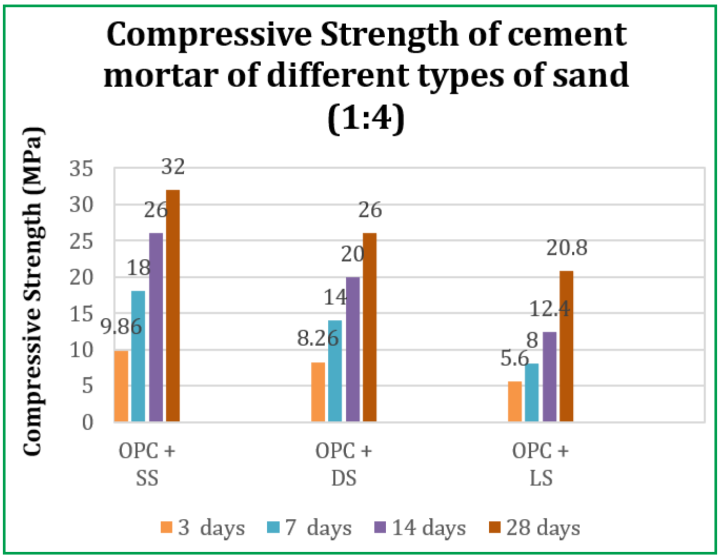

Figure 8. Compressive strength of cement mortar of different types of sand (mix ratio 1:4)

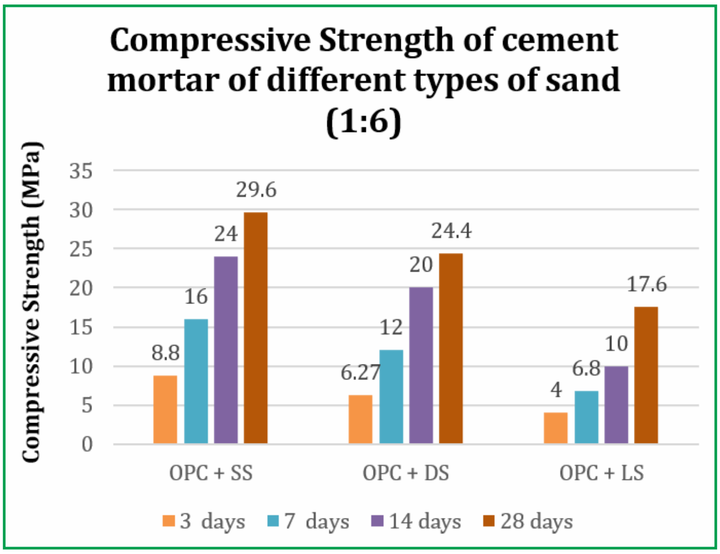

Figure 9. Compressive strength of cement mortar of different types of sand (mix ratio 1:6)

Table 2. Compressive Strength of cement mortar mixing multiple types of sand (cement to sand mix ratio 1:4 and 1:6)

	Cement to Sand mix ratio 1:4				**Cement to Sand mix ratio 1:6**			
Mixing Composition	Average compressive strength (MPa) for different curing days				Average compressive strength (MPa) for different curing days			
	3 days	7 days	14 days	28 days	3 days	7 days	14 days	28 days
OPC+ 50% LS + 50% DS	7.2	12	16.8	24	5.6	9.2	16	22
OPC+ 50% SS + 50% LS	7.6	12.8	19.2	26.8	6.4	14.4	18.8	24
OPC+ 50% DS + 50% SS	8.93	16.8	23.2	29.2	8.8	16	21.6	27.2

Figures 10 and 11 show the effect of combining two sand types in equal proportions. The Sylhet–Domar combination achieved the highest compressive strengths for both mix ratios (1:4 and 1:6), indicating a synergistic packing effect that improved density and strength.

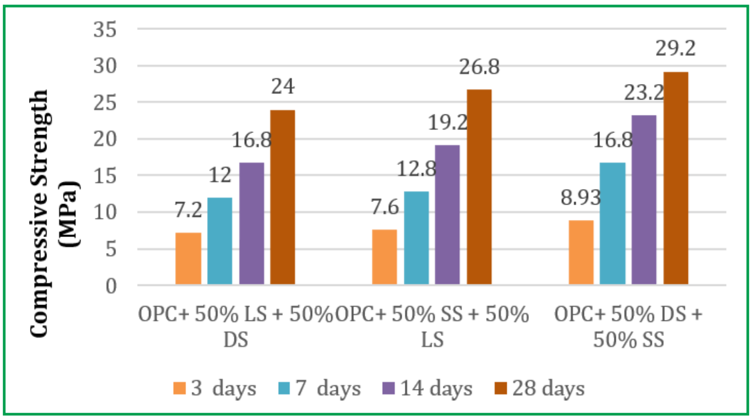

Figure 10. Compressive strength of cement mortar mixing multiple types of sand (1:4)

The Sylhet–local blend produced intermediate performance for all mixes, while the Domar–Local blend yielded the lowest, confirming that replacing inferior sand with better-graded sand can significantly enhance overall performance.

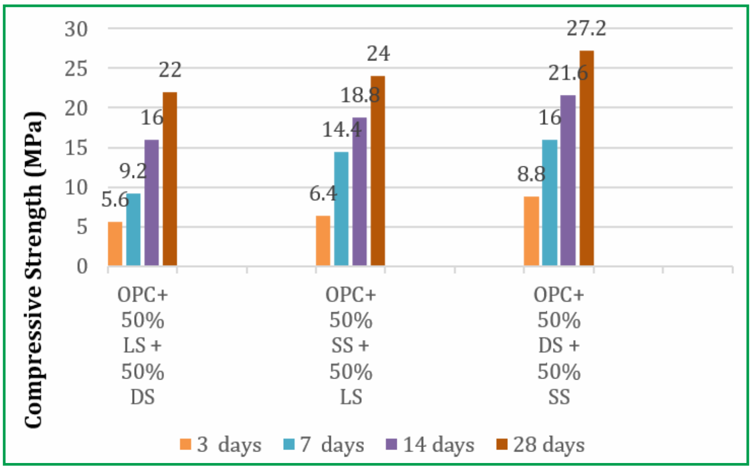

Figure 11. Compressive strength of cement mortar mixing multiple types of sand (1:6)

Comparative Discussion

Using Cement and Single Sand Type in a Mixture

From Figures 12 and 13, the compressive strength development of concrete prepared with OPC and different fine aggregates indicates a clear influence of sand quality on performance, with Sylhet Sand yielding the highest strength at all curing ages and for both the mix ratios (1:4 and 1:6) followed by Domar Sand and local sand. The superior performance of Sylhet Sand may be attributed to its favorable particle gradation, angular shape, and relative cleanliness, which enhance the interfacial bond between the aggregate and cement paste, thereby facilitating higher strength gain over time. Domar Sand, while producing lower strength compared to Sylhet Sand, still demonstrates acceptable performance, possibly due to moderately adequate gradation and particle properties, though minor deficiencies may reduce the efficiency of paste–aggregate bonding.

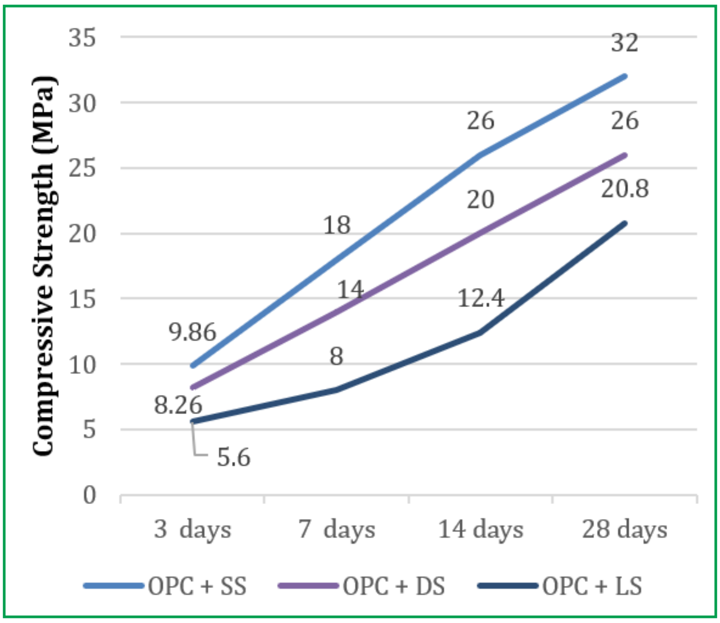

Figure 12. Comparison of compressive strength of cement mortar of different types of sand (mix ratio 1:4)

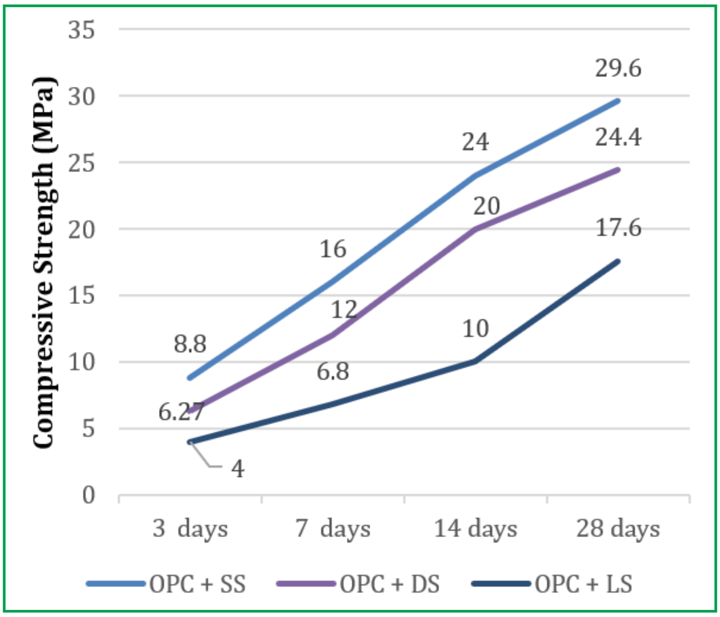

Figure 13. Comparison of compressive strength of cement mortar of different types of sand (mix ratio 1:6)

In contrast, local sand results in substantially lower strength development, likely due to poor grading, the presence of impurities, and an excessive proportion of fines, which can increase water demand and reduce the overall compactness of the mix. These findings underscore the critical role of fine aggregate properties in governing the mechanical performance of concrete, with Sylhet Sand being

https://doi.org/10.70028/sgm.v2i2.62

the most suitable for structural applications, Domar Sand serving as a viable but less efficient alternative, and local sand being inadequate for structural-grade concrete without improvement or blending with higher-quality sand.

Using Cement and Multiple Sand Type in a Mixture

Figures 14 and 15 illustrate the compressive strength development of concrete mixes prepared with OPC and different 50:50 sand combinations, showing that all blends exhibit strength gain with curing age, but at different rates and magnitudes. Among the three combinations, OPC with 50% Domar Sand + 50% Sylhet Sand consistently achieves the highest strengths for both the mix ratios (1:4 and 1:6) indicating that combining two relatively high-quality sands enhances both early and long term strength. OPC with 50% Sylhet Sand

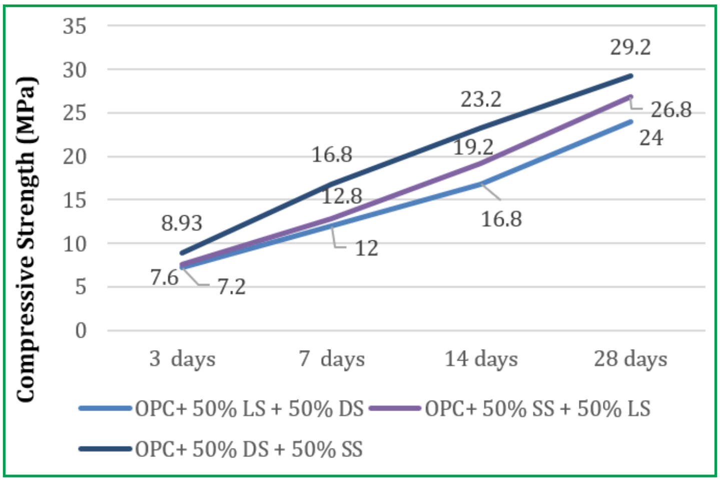

Figure 14. Comparison of compressive strength of cement mortar mixing multiple types of sand (1:4)

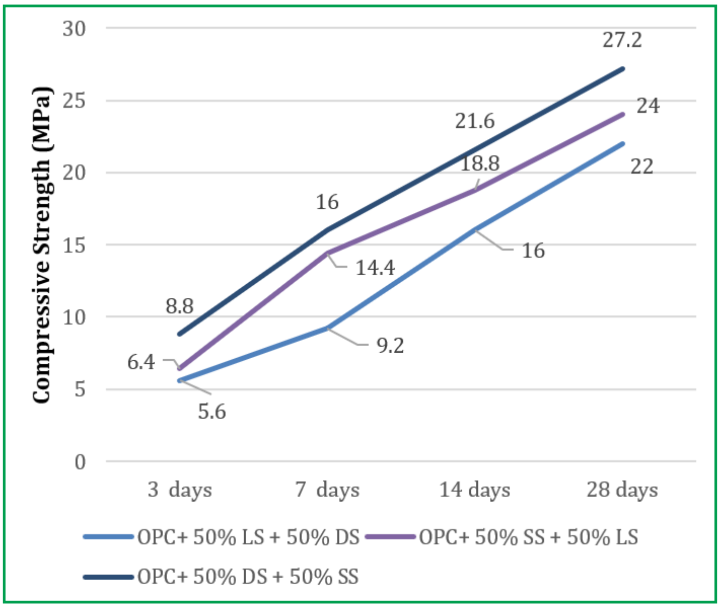

Figure 15. Comparison of compressive strength of cement mortar mixing multiple types of sand (1:6)

https://doi.org/10.70028/sgm.v2i2.62

+ 50% local sand shows intermediate performance, which suggests that partial replacement of inferior local sand with superior Sylhet Sand significantly improves strength while still trailing behind the Domar–Sylhet blend.

In contrast, OPC with ½ local sand + ½ Domar Sand records the lowest strengths though it still demonstrates improvement over mixes made with only local sand. Overall, the results highlight that blending higher quality sands such as Sylhet and Domar yields synergistic effects on concrete strength, while partial replacement of local sand can improve performance but not to the same extent.

Effect of Curing Period

As expected, compressive strength increased with curing time for all mixes. The most significant gain was observed between 7 and 28 days, with 28-day strengths approximately 60% higher than 7-day strengths. This trend corresponds to the ongoing hydration of cement, where additional C–S–H gel forms and fills voids within the mortar matrix. Strength development is particularly sensitive to curing duration when fine aggregates differ in fineness.

Influence of Mix Ratio (1:4 vs. 1:6)

Mortars with the 1:4 cement-to-sand ratio consistently outperformed those with the 1:6 ratio across all curing periods. This outcome is expected, as higher cement content increases the availability of hydration products, thereby improving bond strength and reducing porosity. However, the 1:6 mix remains relevant in practice due to its cost-effectiveness in non-structural applications, despite lower strength values. Previous studies confirm that leaner mixes sacrifice compressive strength but remain suitable where loads are less critical.

Conclusion

This study investigated the effect of sand type and fineness on the compressive strength of cement mortar cubes prepared with different mix ratios and curing periods. Based on the experimental results and analysis, the following conclusions can be drawn:

I. Influence of Sand Type: Sylhet sand consistently produced the highest compressive strength across all curing ages and mix ratios, followed by Domar sand, while local sand exhibited the lowest performance due to its poor gradation and higher fines content. Sylhet sand achieved 32 MPa at 28 days, approximately 54% higher than local sand (20.8 MPa) and 22% higher than Domar sand (26 MPa) for 1:4 mix ratio and for 1:6 mix ratio Sylhet sand (29.6 MPa) achieved 21% higher strength than Domar sand (24.4MPa) and 68% higher than local sand(17.6 MPa) at 28 days.

II. Effect of Mix Ratio: Mortars with a 1:4 cement-to-sand ratio (maximum 32 MPa for Sylhet sand) outperformed those with a 1:6 ratio (maximum 29.6 MPa for Sylhet sand) for all types of sands, confirming that higher cement content contributes to greater strength development. However, the 1:6 ratio remains suitable for non-structural applications where economy is a priority.

https://doi.org/10.70028/sgm.v2i2.62

III. Role of Curing: Compressive strength increased with curing age, with 28-day strength values approximately 60% higher than 7-day strengths for all combinations of mortar. For 1:4 mix ratio Sylhet sand shows compressive strength value of 32 MPa for 28 days curing where 7 days curing strength is 9.86 MPa and for 1:6 mix ratio the value for 28 days curing is 29.6 MPa where for 7 days is 8.8 MPa. This emphasizes the importance of adequate curing in achieving the desired performance of mortar.

IV. Sand Blending: Mixtures of Sylhet and Domar sands showed synergistic effects, producing higher strengths (29.2 MPa for 1:4 ratio in 28 days curing and 27.2 MPa for 1:6 ratio) than either sand used alone. Other combinations show lower values, combination of Sylhet and local sand shows 26,4 MPa and 24 MPa for 1:4 and 1:6 ratios respectively in 28 days curing period where combination of local and Domar sand shows a relatively lower value of 24 MPa and 22 MPa for 1:4 and 1:6 ratios respectively for 28 days curing period. This suggests that careful blending of sands with different gradations can optimize mortar properties.

V. Practical Implications: For construction in Bangladesh, Sylhet sand or Sylhet-Domar blends are recommended when higher strength is required. Local sand, while widely available, may only be suitable for low-strength or temporary applications.

VI. Future Research: Further studies should examine the durability aspects of mortars prepared with different sands, including resistance to sulfate attack, carbonation, and freeze-thaw cycles. Investigating the performance of these sands in reinforced masonry and concrete applications would also provide valuable insights.

List of Abbreviations

SS Sylhet Sand

DS Domar Sand

LS Local Sand

Acknowledgement

The authors express their gratitude to the Department of Civil Engineering, Dhaka International University, Dhaka, Bangladesh, for their support in this research through the provision of laboratory facilities.

Conflicts of Interest

The authors declare no conflicts of interest

Author Contributions

Imon Hasan Bhuiyan: writing-original draft, conceptualization, methodology. **Abdul Awol Rabby:** investigation, data curation, review and editing. **Abhijit Nath Abhi:** resources, validation.

Data Availability Statement

The data used to support the findings of this study are included within the article.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

In preparing this work, the authors used ChatGPT to improve the clarity of the writing. The content was subsequently reviewed and edited by the authors and take full responsibility for the final publication.

References

[1] M. Caroselli, S. A. Ruffolo, and F. Piqué, "Mortars and plasters—how to manage mortars and plasters conservation," Archaeol. Anthropol. Sci., vol. 13, no. 11, 2021, doi: http://dx.doi.org/10.1007/s12520-021-01409-x.

[2] M. Stepinac, T. Kisicek, T. Renić, I. Hafner, and C. Bedon, "Methods for the assessment of critical properties in existing masonry structures under seismic loads-the ARES project," Appl. Sci., vol. 10, no. 5, 2020, doi: http://dx.doi.org/10.3390/app10051576

[3] Narendra Kumar, A. Verma, and T. A. Kumar, "'Effect of Time on Compressive Strength of Cement Mortar,'" vol. 5, no. 1, pp. 1–5, 2018.

[4] Y. Adam Nabage, A. Mani Umar, I. M. Bala, and A. Abdulrahman, "Performance Assessment of Curing Techniques on Pozzolanic Concrete," Smart Green Mater., vol. 2, no. 2, pp. 74–91, 2025, doi: http://dx.doi.org/10.70028/sgm.v2i2.43

[5] H. Wang, J. Shen, Q. Shahzad, X. Sun, and W. Dong, "Performance Optimization of Green Mortar Using Graded Ferrochrome Slag and Dune Sand as Aggregates," Int. J. Concr. Struct. Mater., vol. 19, no. 1, 2025, doi: http://dx.doi.org/10.1186/s40069-025-00826-9

[6] N. Badr, M. R. Irshidat, and O. Maglad, "Utilizing Recycled Sand from Excavation Wastes for Sustainable Cement Mortar Production," Civ. Eng. J., vol. 10, no. 6, pp. 1909–1921, 2024, doi: http://dx.doi.org/10.28991/CEJ-2024-010-06-012

[7] J. Skocek, A. Ouzia, E. Vargas Serrano, and N. Pato, "Recycled Sand and Aggregates for Structural Concrete: Toward the Industrial Production of High-Quality Recycled Materials with Low Water Absorption," Sustain., vol. 16, no. 2, 2024, doi: http://dx.doi.org/10.3390/su16020814

[8] S. Chafika, I. Ilyes, D. Farid, and K. Elhadj, "Rheological behaviour of cement mortar with recycled organic sand," Rev. la Constr., vol. 23, no. 3, pp. 639–651, 2024, doi: http://dx.doi.org/10.7764/RDLC.23.3.639

[9] T. Li, Y. Zhou, J. Zhu, and J. Liu, "Effect of fine aggregate gradation on the rheology of mortar," Constr. Build. Mater., vol. 332, p. 127362, May 2022, doi: http://dx.doi.org/10.1016/J.CONBUILDMAT.2022.127362

[10] B. Arulmoly, C. Konthesingha, and A. Nanayakkara, "Performance evaluation of cement mortar produced with manufactured sand and offshore sand as alternatives for river sand," Constr. Build. Mater., vol. 297, p. 123784, Aug. 2021, doi: http://dx.doi.org/10.1016/J.CONBUILDMAT.2021.123784

[11] A. El-Husseiny, "Improved packing model for functionally graded sand-fines mixtures-incorporation of fines cohesive packing behavior," Appl. Sci., vol. 10, no. 2, pp. 23–26, 2020, doi: http://dx.doi.org/10.3390/app10020562

[12] S. K. Ling and A. K. H. Kwan, "Adding ground sand to decrease paste volume, increase cohesiveness and improve passing ability of SCC," Constr. Build. Mater., vol. 84, pp. 46–53, Jun. 2015, doi: http://dx.doi.org/10.1016/j.conbuildmat.2015.03.055

[13] G. E. Djepaze, y., Kagonbe, B., Medi Balo, A., Kamseu, E., Ntamack, "Influence of the fineness modulus of sand on the compressive strength of its corresponding mortar," Sci. Technol. Publ. (SCI &TECH, vol. 4, no. 7, pp. 308–315, 2020

[14] X. He, J. Gao, Y. Liu, Y. Fang, D. Qiao, and W. Shen, "Gradation optimization of continuous-graded crushed sand based on mortar performance," Constr. Build. Mater., vol. 358, p. 129423, Dec. 2022, doi: http://dx.doi.org/10.1016/j.conbuildmat.2022.129423

[15] P. Nath and P. K. Sarker, "Use of OPC to improve setting and early strength properties of low calcium fly ash geopolymer concrete cured at room temperature," Cem. Concr. Compos., vol. 55, pp. 205–214, Jan. 2015, doi: http://dx.doi.org/10.1016/J.CEMCONCOMP.2014.08.008

[16] S. Jahagirdar, V. Patki, and S. Metan, "Evaluation of physical and chemical properties of OPC and PPC cement," Int. J. Recent Technol. Eng., vol. 8, no. 2 Special Issue 11, pp. 840–845, 2019, doi: http://dx.doi.org/10.35940/ijrte.B1138.0982S1119

[17] Basha Fayissa, "Comparative Study on Compressive Strength of Demolished Concrete Aggregate and Conventional Concrete Aggregate for Construction Materials," Int. J. Eng. Res., vol. V7, no. 12, 2018, doi: http://dx.doi.org/10.17577/ijertv7is120040

[18] S. A. Fadil, G. Y. Al Kindi, and S. B. Tobeia, "Effect of Water Quality (Pollutants) on Concrete Properties (Review)," J. Optoelectron. Laser, vol. 41, no. 6, pp. 248–257, 2022, [Online]. Available: http://www.gdzjg.org/index.php/JOL/article/view/515

[19] R. L. S. Ferreira et al., "Effects of Particle Size Distribution of Standard Sands on the Physical-Mechanical Properties of Mortars," Materials (Basel)., vol. 16, no. 2, 2023, doi: http://dx.doi.org/ 10.3390/ma16020844

[20] J. A. Ige, A. A. Alabi, A. O. Adejumobi, J. A. Ayanlola, M. O. Ogunjinmi, and A. O. Oladiji, "The Effect of Fineness Modulus of Fine Aggregate on Concrete Compressive Strength," LAUTECH J. Civ. Environ. Stud., vol. 12, no. 1, pp. 27–33, 2024, doi: http://dx.doi.org/10.36108/laujoces/4202.21.0130

[21] P. Chindaprasirt, N. Buapa, and H. T. Cao, "Mixed cement containing fly ash for masonry and plastering work," Constr. Build. Mater., vol. 19, no. 8, pp. 612–618, Oct. 2005, doi: http://dx.doi.org/ 10.1016/J.CONBUILDMAT.2005.01.009

[22] W. Zhang, M. Zheng, L. Zhu, and Y. Lv, "Mix design and characteristics evaluation of high-performance concrete with full aeolian sand based on the packing density theory," Constr. Build. Mater., vol. 349, p. 128814, Sep. 2022, doi: http://dx.doi.org/10.1016/J.CONBUILDMAT.2022.128814