Problems related to use of artificial sand during its field application

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ABSTRACT - The increasing demand for construction materials and the depletion of natural river sand have led to the widespread adoption of artificial sand as an alternative fine aggregate. Although artificial sand offers advantages such as controlled production, better availability, and environmental sustainability, its use in field applications has revealed several challenges related to workability, strength, permeability, and crack formation. These issues primarily arise due to the angular particle shape, higher fines content, and increased water absorption characteristics of artificial sand.

This study investigates the performance of artificial sand in mortar applications, with particular emphasis on field-related problems such as shrinkage, reduced workability, and surface cracking. Experimental analysis was carried out using different mix proportions, and the influence of material properties such as gradation, silt content, and moisture behavior was evaluated. The results indicate that although artificial sand improves compressive strength due to enhanced interlocking, it simultaneously increases water demand and susceptibility to shrinkage-induced cracking.

To address these limitations, the incorporation of Super Absorbent Polymer (SAP), specifically sodium polyacrylate, was examined as a potential solution. SAP acts as an internal curing agent by absorbing and gradually releasing water within the mortar matrix, thereby reducing moisture loss and internal stresses. The inclusion of SAP was found to improve crack resistance, enhance durability, and reduce external curing requirements.

The study concludes that while artificial sand is a viable and sustainable alternative to natural sand, its performance can be significantly enhanced through the use of advanced materials such as SAP and proper control of mix design parameters. The findings provide practical insights for improving the field application of artificial sand in mortar and plastering works.

Key Words: Artificial Sand, Manufactured Sand, Cement Mortar, Fine Aggregate Properties, Workability, Compressive Strength, Shrinkage Cracks, Gradation Analysis, Durability

1.INTRODUCTION

The rapid expansion of the construction sector has significantly increased the demand for concrete and mortar, which are essential components of modern infrastructure. Fine aggregates, particularly sand, play a crucial role in these materials by filling voids, improving density, and enhancing overall strength. Traditionally, natural river sand has been widely used for this purpose. However, excessive extraction has led to serious environmental concerns such as riverbed degradation, ecological imbalance, and depletion of available resources. As a result, the construction industry is actively seeking sustainable alternatives.

Artificial sand, commonly referred to as manufactured sand

or M-sand, is produced by mechanically crushing rocks or quarry materials into fine particles. Due to its controlled production process, it offers advantages such as uniform gradation and minimal presence of harmful impurities. Its angular particle shape also contributes to better interlocking within the cement matrix. These characteristics make artificial sand a viable substitute for natural sand in various construction activities.

Despite these benefits, the use of artificial sand in mortar and plaster applications has revealed several practical limitations. The presence of excessive fines and dust content tends to increase water demand, which affects workability and consistency. In many cases, this leads to issues such as poor bonding, uneven surface finishing, and the formation of shrinkage cracks. These problems are more prominent in field conditions where quality control is limited.

The performance of cement mortar is influenced by multiple factors including mix proportion, water-cement ratio, particle size distribution, and curing practices. When artificial sand is used without proper control of these parameters, variations in strength and durability may occur. Therefore, it becomes necessary to evaluate its properties systematically and understand its behavior in real construction scenarios.

This study aims to investigate the characteristics of artificial sand and analyze its impact on mortar performance through experimental testing. The goal is to identify the causes of field-related issues and suggest practical measures to improve the efficiency and reliability of artificial sand in construction applications.

2. EASE OF USE

Ease of use is an important factor in evaluating the suitability of artificial sand for construction applications, particularly in mortar and plastering works. Compared to natural sand, artificial sand often exhibits angular particle shapes and a higher proportion of fines, which influence its handling and application. While the controlled gradation of artificial sand can improve consistency in batching, its increased water demand may reduce workability if not properly managed. This can make mixing, spreading, and finishing operations more laborintensive in field conditions.

Additionally, the presence of dust and moisture variations can affect the uniformity of the mix, leading to difficulties during application such as poor flow and reduced cohesion. However, with proper processing techniques such as washing, grading control, and the use of admixtures like plasticizers, the ease of use of artificial sand can be significantly improved. When appropriately treated and proportioned, artificial sand can provide satisfactory workability and application performance comparable to natural sand, making it a practical alternative in modern construction practices.

3. LITERATURE SURVEY

The rapid growth of the construction industry has led to excessive consumption of natural resources, particularly river sand, which is widely used as a fine aggregate in mortar and concrete. Due to the depletion of natural sand reserves and environmental concerns, researchers have increasingly focused on alternative materials such as artificial sand, industrial by-products, and modified mortar systems. However, while these alternatives offer sustainability benefits, they also introduce challenges related to workability, strength, durability, and crack formation. This section presents a comprehensive review of previous studies on artificial sand, alternative aggregates, admixtures, and advanced techniques for improving mortar performance.

The use of admixtures and supplementary cementitious materials has been extensively studied to enhance the performance of mortar. Munisha and Sakthieswaran (2020) investigated the effect of natural admixtures along with silica fume and fly ash in blended mortar systems [1]. Their study showed that partial replacement of cement with 15% fly ash and silica fume, combined with 0.5% natural admixture, resulted in improved compressive strength and durability. The research also highlighted that heat curing significantly enhances early-age strength compared to conventional water curing. These findings demonstrate that the use of natural and industrial admixtures can effectively improve mortar performance while reducing reliance on cement.

Similarly, Sun et al. (2019) studied high-performance cement mortar for semi-flexible pavement applications [4]. The authors found that the incorporation of polycarboxylate superplasticizers, expansion agents, and accelerators significantly improves workability, strength development, and shrinkage control. The study emphasized that the water-binder ratio and admixture dosage are critical factors influencing the overall performance of mortar. These results are particularly relevant for artificial sand-based systems, where workability issues are commonly observed.

The replacement of natural sand with alternative materials has also been widely explored. Qian et al. (2020) examined the use of sintered fly ash aggregates in geopolymer mortars as a complete replacement for natural sand [2]. Their findings indicated that although compressive strength was slightly lower than conventional mortar, the system exhibited reduced drying shrinkage due to internal curing effects. However, increased porosity and reduced flowability were observed, suggesting limitations in practical applications. This highlights the trade-off between sustainability and performance when using alternative aggregates.

Soni and Sharma (2020) analyzed the mechanical properties of concrete containing crushed recycled aggregates as a substitute for natural sand [8]. The study demonstrated that with proper gradation and packing density, recycled aggregates can achieve improved compressive, tensile, and flexural strength. Microstructural analysis confirmed enhanced bonding characteristics, indicating that engineered aggregates can serve as viable alternatives to natural sand. However, the variability in material properties requires careful quality control.

Further research by Kaish (2021) investigated the use of industrial waste materials such as alum sludge, quarry dust, and limestone dust as partial replacements for fine aggregates. The study concluded that these materials act as effective fillers, improving density and strength when used in optimum proportions (10–15%). However, excessive replacement leads to a reduction in strength, emphasizing the importance of proper mix design and proportioning.

The mechanical performance of mortar is strongly influenced by mix design and particle packing. Gupta et al. (2020) developed high-performance hybrid fiber reinforced concrete using different fine aggregates and the Modified Andreasen and Andersen particle packing model [6]. Their results showed that optimized particle packing significantly enhances mechanical and durability properties. The study also found that the performance difference between natural sand and standard sand is minimal when proper mix design techniques are applied. This suggests that material limitations can be overcome through scientific optimization.

Sharifi et al. (2019) applied an improved Taguchi optimization method for designing high-strength self-compacting concrete [9]. The research highlighted the importance of systematic optimization techniques in achieving the desired balance between workability and strength. Such approaches are particularly useful for artificial sand applications, where variability in particle size distribution and fines content can affect performance.

Han and Han (2021) proposed a quantitative method for evaluating segregation in concrete [7]. Their findings indicated that improper gradation and excessive fines lead to segregation, which negatively impacts structural integrity. This is a critical concern in artificial sand-based systems, where higher fines content is commonly observed.

Crack formation is one of the most significant issues affecting mortar performance. Bochen (2009) studied the influence of simulated weathering on plaster microstructure and found that environmental exposure leads to increased porosity and changes in mineral composition, resulting in higher permeability and crack development. These findings highlight the importance of controlling environmental conditions and material properties to reduce cracking. Further studies on weathering effects showed that ageing processes lead to microstructural transformations such as calcite formation and increased permeability, which weaken the material over time.

Shia (2020) investigated shrinkage-compensating cement and found that while it reduces shrinkage, it also increases permeability and the risk of reinforcement corrosion. This indicates that improvements in one property may lead to deterioration in another, emphasizing the need for balanced material design.

The use of fibers and composite materials has been explored as a method to control crack propagation. Hossam El-Din (2020) studied the application of glass fiber reinforced polymer (GFRP) and found that fiber reinforcement significantly improves ductility and reduces crack propagation. Similarly, hybrid fiber systems have been shown to enhance tensile strength and reduce crack width, thereby improving durability [6].

Recent advancements in self-healing materials have introduced innovative solutions for crack mitigation. Studies on bacterial concrete have shown that microbial activity can induce calcite precipitation, which fills cracks and reduces permeability. This approach improves the long-term durability of structures and reduces maintenance requirements. Additionally, the use of superabsorbent polymers (SAPs) has been found to reduce shrinkage and prevent early-age cracking by acting as internal curing agents.

Bullard et al. (2017) emphasized the need for advanced modeling and material characterization to develop next-generation concrete binders [10]. The study highlighted the importance of understanding structure-property relationships to improve material performance. Similarly, Santosa et al. (2019) demonstrated that eco-friendly earth plasters can perform effectively under controlled conditions, offering sustainable alternatives for construction [3]. Seller (2016) also discussed the challenges and opportunities in developing advanced construction materials, emphasizing the need for innovation to address sustainability concerns [5].

In summary, the literature indicates that artificial sand and alternative materials provide a sustainable solution to the depletion of natural resources. However, their application introduces challenges related to workability, shrinkage, and cracking. The use of admixtures, fibers, and advanced technologies such as self-healing materials can effectively address these issues. Optimized mix design, proper curing, and control of fines content are essential for achieving desired performance. Despite significant advancements, further research is required to develop standardized guidelines and improve the field performance of artificial sand in construction applications.

4. PROBLEM FORMULATION

The increasing demand for construction materials and the depletion of natural river sand have led to the widespread use of artificial sand as an alternative fine aggregate. While artificial sand offers advantages such as controlled production, better availability, and absence of organic impurities, its application in mortar and plaster has introduced several practical challenges.

One of the major issues associated with artificial sand is its angular particle shape and higher fines content, which significantly affect the workability of mortar. Due to reduced workability, additional water is often added at construction sites to achieve the desired consistency. However, this practice alters the water-cement ratio, leading to reduced strength and durability of the mortar.

Another critical problem is the increased tendency for shrinkage and crack formation in artificial sand mortar. The higher surface area and water absorption capacity of artificial sand result in rapid moisture loss, causing volumetric changes and internal stresses. These stresses lead to the development of various types of cracks such as shrinkage cracks, surface cracks, and heaving cracks, which adversely affect the serviceability of structures.

Furthermore, the variability in properties of artificial sand due to differences in quarry sources, particle size distribution, and dust content results in inconsistent performance. The lack of standardized guidelines for controlling these properties makes it difficult to achieve uniform quality in construction applications.

In addition, most existing studies focus on laboratory-based analysis and concrete applications, while limited attention has been given to the performance of artificial sand in plastering works under real field conditions. The influence of environmental factors such as temperature, humidity, and curing practices on crack formation and durability has not been adequately addressed.

Therefore, the problem addressed in this study is to evaluate the performance of artificial sand in mortar applications, identify the causes of workability issues and crack formation, and propose suitable measures to improve its behavior for practical construction use.

5. METHODOLOGY

The present study is carried out to evaluate the performance of artificial sand in mortar applications with a focus on strength characteristics, workability, and crack formation behavior. The methodology is divided into two major phases, namely Phase I (Material Characterization and Mix Design) and Phase II (Experimental Investigation and Performance Evaluation). This structured approach ensures a systematic understanding of material properties and their influence on mortar performance.

5.1 Phase I: Material Characterization and Mix Design

Phase I focuses on understanding the fundamental properties of artificial sand and developing suitable mortar mix proportions.Initially, materials such as Ordinary Portland Cement, artificial sand, and potable water were selected. Artificial sand samples were collected from quarry sources to capture variations in gradation, silt content, and moisture characteristics. These variations are critical as they directly influence the behavior of mortar in practical applications.

To evaluate the physical properties of artificial sand, sieve analysis was performed using standard IS sieves. The grading characteristics were determined to ensure conformity with required standards. Proper gradation is essential for achieving a dense packing of particles, which improves the strength and durability of mortar.

The silt content test was conducted to determine the percentage of fine particles present in the sand. Excessive fines adversely affect bonding and increase water demand, leading to shrinkage and cracking.

Further, specific gravity and bulk density tests were carried out to establish the weight-volume relationship of the material. These parameters are essential for accurate mix proportioning. Moisture content was also determined, as artificial sand tends to absorb more water due to its higher surface area and porosity.

The mix design of mortar was then carried out using standard proportions of 1:4, 1:5, and 1:6 (cement:sand ratio). The dry materials were mixed thoroughly to ensure uniform distribution before adding water.

The dry volume of mortar was calculated using the relation:

$$V_d = 1.33 \times V_w$$

Where,

V_d= Dry volume of mortar
V_w= Wet volume of mortar

The quantity of cement required was calculated using:

$$\text{Quantity of Cement} = \frac{V_d \times C}{C + S}$$

Where,

C= Cement ratio
S= Sand ratio

The water requirement was determined based on the water-cement ratio:

$$W = (w/c) \times C$$

Where,

W= Weight of water
w/c= Water-cement ratio

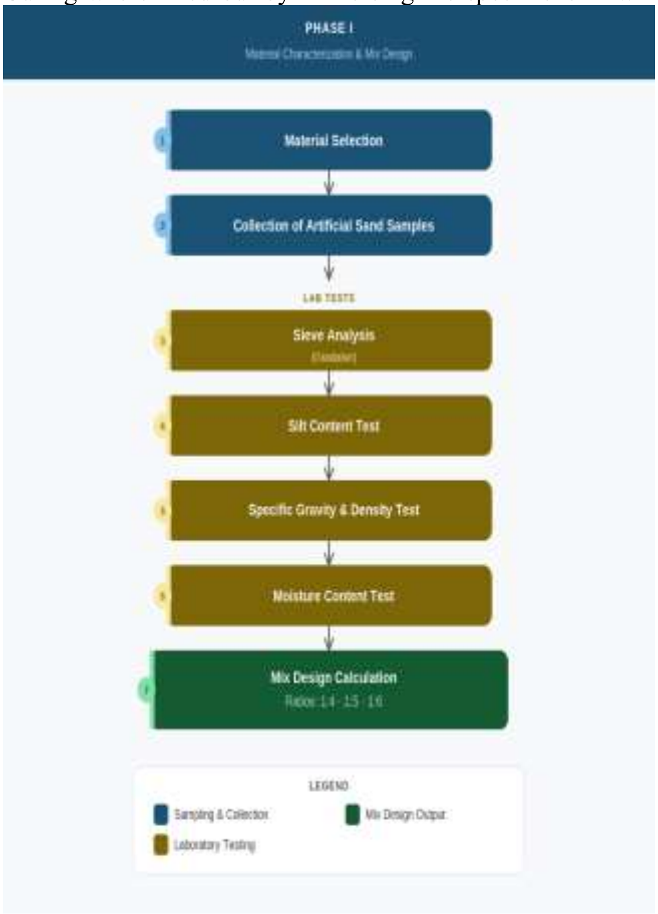
These calculations ensured proper proportioning of materials for achieving desired consistency and strength.

5.2 Phase II: Experimental Investigation and Performance Evaluation

Phase II involves the preparation of specimens, curing, and testing to evaluate the performance of artificial sand mortar.

Mortar specimens were prepared using cube molds of standard dimensions. The prepared mix was placed in molds in layers, and each layer was compacted properly to eliminate air voids and ensure uniform density. After casting, the specimens were kept undisturbed for 24 hours and then demolded.

Curing was carried out by immersing the specimens in water for 7 days and 28 days. Proper curing is essential for hydration of cement and development of strength. The curing process also influences the microstructure and durability of mortar.



After curing, compressive strength tests were conducted using a compression testing machine. The load was applied gradually until failure, and the maximum load was recorded. The compressive strength was calculated using:

$$f_c = \frac{P}{A}$$

Where,

f_c= Compressive strength (MPa)
P= Load at failure (N)
A= Cross-sectional area (mm²)

Shrinkage behavior was evaluated by measuring dimensional changes in the specimens after drying. The reduction in dimensions indicates volumetric changes, which are responsible for shrinkage cracks. Visual observations were made to identify crack patterns such as shrinkage cracks, surface cracks, and heaving cracks

6.RESULTS AND DISCUSSION

The experimental investigation carried out in this study provides a detailed understanding of the behavior of artificial sand in mortar applications. The results obtained from various tests, including sieve analysis, silt content determination, compressive strength testing, and shrinkage evaluation, are analyzed and discussed in this section.

6.1 Analysis of Sieve Distribution and Gradation

The sieve analysis results indicate that a significant percentage of artificial sand particles are concentrated in the size range of 1.18 mm to 600 µm. This suggests that artificial sand predominantly falls within medium to coarse grading zones. However, a noticeable percentage of particles passing through the 300 µm sieve contributes to the presence of fines or dust content.

The fineness modulus values obtained for different samples vary, indicating inconsistency in gradation across quarry sources. Samples with higher fineness modulus values exhibit coarser particles, which improve strength due to better interlocking. On the other hand, samples with lower fineness modulus values contain higher fines, leading to increased water demand and reduced workability.

This variation in gradation directly affects the packing density and bonding characteristics of mortar. Well-graded sand provides a dense matrix, whereas poorly graded sand results in voids and weak zones within the mortar structure.

6.2 Effect of Silt Content on Mortar Performance

The silt content analysis shows that the percentage of fine particles varies significantly among different artificial sand samples. It is observed that samples with silt content below approximately 12–14% exhibit better performance in terms of workability and finishing.

Higher silt content increases water demand, as fine particles absorb more water and reduce the availability of free water for cement hydration. This results in reduced bonding strength and increased shrinkage. Additionally, excessive fines create a weak interface between cement paste and aggregate, which negatively affects compressive strength.

Therefore, controlling silt content is essential for maintaining the quality and consistency of artificial sand used in mortar applications.

6.3 Compressive Strength Behavior

The compressive strength results show a clear trend of strength development with curing time. At 7 days, the strength values are relatively low for all mix proportions, indicating that early-age strength development is limited. However, a significant increase in strength is observed at 28 days due to continued hydration of cement.

Among the different mix proportions, the 1:4 mix exhibits the highest compressive strength, followed by 1:5 and 1:6 mixes. This is attributed to the higher cement content in the 1:4 mix, which enhances the bonding and load-carrying capacity of the mortar.

The relationship between compressive strength and mix proportion can be expressed as:

$$\boldsymbol{f_c \propto \frac{1}{(w/c)}}$$

where the strength increases as the water-cement ratio decreases.

Artificial sand contributes to improved strength due to its angular particle shape, which provides better mechanical interlocking compared to natural sand. However, this advantage is partially offset by increased water demand and reduced workability.

6.4 Influence of Moisture Content and Water Demand

The moisture content of artificial sand plays a crucial role in determining the effective water-cement ratio of the mortar mix. Due to its higher porosity and surface area, artificial sand absorbs more water compared to natural sand.

This absorption reduces the availability of free water required for proper hydration of cement. As a result, additional water is often added during mixing to achieve the desired consistency. However, excessive water leads to segregation and reduces the strength of mortar.Thus, maintaining an optimal water-cement ratio is essential for balancing workability and strength.

6.5 Shrinkage Behavior and Crack Formation

Shrinkage analysis reveals that artificial sand mortar is more prone to volumetric changes due to higher water absorption and evaporation rates. The reduction in specimen dimensions after drying indicates the presence of drying shrinkage.

The shrinkage strain can be expressed as:

$$\boldsymbol{\epsilon_s = \frac{\Delta L}{L}}$$

Where,

ϵ_s= shrinkage strain
ΔL= change in length
L= original length

Visual observations indicate the formation of different types of cracks, including surface cracks, shrinkage cracks, and heaving cracks. These cracks are primarily caused by internal stresses generated due to moisture loss and differential volume changes.

6.6 Effect of Mix Proportion on Overall Performance

The comparison of different mix proportions shows that increasing cement content improves strength but reduces workability. The 1:4 mix provides higher strength but requires careful control of water content to avoid shrinkage and cracking.

The 1:5 mix offers a balanced performance in terms of strength and workability, making it suitable for general mortar applications. The 1:6 mix, although more economical, exhibits lower strength and higher susceptibility to cracking.

This indicates that mix proportion plays a critical role in determining the performance of artificial sand mortar.

6.7 Overall Performance Evaluation of Artificial Sand

The overall analysis indicates that artificial sand can be effectively used as a replacement for natural sand in mortar applications, provided that its properties are properly controlled. The angular shape of particles enhances strength, while higher fines content and water absorption pose challenges related to workability and durability.

The key factors influencing performance include gradation, silt content, water-cement ratio, and curing conditions. Proper control of these parameters can significantly improve the behavior of artificial sand mortar.

6.8 Field Observations and Role of Super Absorbent Polymer (SAP)

Field observations were carried out to evaluate the behavior of artificial sand mortar under practical site conditions. The results indicate that artificial sand mortar exhibits noticeable moisture loss and shrinkage during early stages of drying. A weight reduction in the range of approximately 18–20% was observed due to evaporation of water from the surface of the specimens. This moisture loss contributes significantly to volumetric shrinkage and the development of surface cracks.

Dimensional analysis of the specimens after drying revealed shrinkage in the range of approximately 0.2 mm to 0.8 mm within 24 hours. This indicates that artificial sand mortar is highly susceptible to early-age shrinkage, primarily due to its higher water absorption capacity and rapid moisture loss.

It was also observed that the application technique plays a crucial role in improving performance. The use of relatively non-graded aggregates in the initial plaster layer helps in better adhesion with the substrate, while the use of properly graded sand in the finishing layer improves surface quality and finishing characteristics. This layered approach enhances both bonding and aesthetic performance.

To address the issue of shrinkage and cracking, the use of Super Absorbent Polymers (SAP) was investigated. SAP materials, particularly sodium polyacrylate, are capable of absorbing a large amount of water relative to their own mass and releasing it gradually over time. This behavior facilitates internal curing within the mortar matrix.

Chemically, sodium polyacrylate is a cross-linked polymer with repeating units of:

$$[-CH_2 - CH(COONa) -]_n$$

This polymer structure contains negatively charged carboxylate groups, which attract and retain water molecules. The absorbed water is later released during hydration, thereby reducing internal stress and preventing premature drying.

Experimental observations indicate that mortar specimens incorporating SAP exhibit improved resistance to high temperatures, sustaining conditions up to 80–90°C without visible cracking. This demonstrates the effectiveness of SAP in reducing thermal and drying stresses.

Furthermore, the inclusion of SAP reduces the external curing water requirement by acting as an internal water reservoir. However, it is important to note that SAP does not function as a direct substitute for water but rather as a regulating agent that improves moisture distribution within the mortar.

The incorporation of SAP also contributes to improved mechanical and durability properties. It enhances plaster stability, reduces crack propagation, and improves resistance to frost action and internal pressure caused by water expansion. Additionally, the flexural strength of mortar is improved due to better stress distribution within the matrix.

Overall, the use of Super Absorbent Polymer in artificial sand mortar provides an effective solution to mitigate shrinkage and cracking issues. It enhances durability, reduces curing dependency, and improves overall performance, making it a promising additive for practical construction applications.

7.CONCLUSION

The present study investigated the performance of artificial sand as a fine aggregate in mortar applications, with a focus on workability, strength characteristics, and crack formation behavior. Based on the experimental results and analysis, the following conclusions can be drawn.

Artificial sand demonstrates significant potential as a replacement for natural sand due to its availability, controlled production, and absence of organic impurities. The angular and rough texture of artificial sand particles contributes to improved mechanical interlocking, resulting in higher compressive strength compared to conventional mortar mixes.

However, the study reveals that artificial sand exhibits higher fines content and water absorption capacity, which adversely affect workability. To achieve the desired consistency, additional water is often introduced, which increases the water-cement ratio and reduces the overall strength and durability of the mortar.

The results indicate that compressive strength increases with curing time, with 28-day strength values significantly higher than 7-day values. Among the different mix proportions, the 1:4 mix exhibited the highest strength due to higher cement content, while the 1:5 mix provided a balanced performance in terms of strength and workability. The 1:6 mix showed lower strength and higher susceptibility to cracking.Shrinkage and crack formation were identified as major challenges in artificial sand mortar. The higher surface area and moisture absorption characteristics of artificial sand lead to increased drying shrinkage, resulting in the formation of surface cracks and heaving cracks. The extent of cracking is influenced by factors such as silt content, water-cement ratio, and curing conditions.

Overall, artificial sand can be effectively used in mortar applications if appropriate mix design, controlled water content, and proper curing practices are adopted. The limitations associated with workability and crack formation can be mitigated through the use of admixtures, improved grading, and optimized construction techniques.

Thus, the study concludes that artificial sand is a viable and sustainable alternative to natural sand, provided that its inherent challenges are addressed through scientific and practical approaches.

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