Advances in Research

Volume 25, Issue 6, Page 192-201, 2024; Article no.AIR.126743
ISSN: 2348-0394, NLM ID: 101666096

A Review on the Shrinkage Properties of Concrete and Influencing Factors

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: https://doi.org/10.9734/air/2024/v25i61192

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:
https://www.sdiarticle5.com/review-history/126743

Commentary

Received: 14/09/2024
Accepted: 16/11/2024
Published: 22/11/2024

ABSTRACT

This paper provides a comprehensive review of the basic concepts of concrete shrinkage, including plastic shrinkage, temperature shrinkage, carbonation shrinkage, drying shrinkage, and autogenous shrinkage. It also discusses the causes, influencing factors, and control measures of these shrinkage types in detail. Among them, drying shrinkage, which is the most important volume stability deformation of concrete, has its mechanism deeply explored, including the theory of capillary tension, the theory of separation pressure, the theory of solid surface tension, and the theory of interlayer water loss. Additionally, this paper discusses and evaluates the current research on the drying shrinkage of mechanism sand concrete and its influencing factors, particularly the effects of stone powder and MB value (methylene blue value) on the drying shrinkage of mechanism sand concrete. Research indicates that in mechanism sand sand concrete, an appropriate stone powder content and optimized mix design can reduce the drying shrinkage of concrete and enhance the overall performance the concrete.

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Cite as: *Zhong, Hao. 2024. "A Review on the Shrinkage Properties of Concrete and Influencing Factors". Advances in Research 25 (6):192-201. https://doi.org/10.9734/air/2024/v25i61192.*

Keywords: Concrete shrinkage; drying shrinkage; manufactured sand; aggregate characteristics.

1. INTRODUCTION

Concrete, as an indispensable material in modern construction, plays a crucial role in ensuring the safety and durability of buildings through its stable and reliable performance. However, the shrinkage behavior of concrete has always been one of the focal issues in both engineering and academic circles. Concrete shrinkage refers to the volume reduction caused by the loss of internal moisture due to factors such as drying, chemical reactions, and temperature changes during setting, hardening, and use. This volume change can not only affect the mechanical properties and durability of concrete but also lead to structural cracking, thereby compromising the overall safety of buildings (Huang and Hui 1990, Dai 2019).

Therefore, conducting in-depth research on the shrinkage behavior of concrete and exploring its mechanisms and influencing factors are of great significance for improving the quality and performance of concrete materials and ensuring the safety and durability of buildings. This paper aims to reveal the laws and characteristics of concrete shrinkage behavior through a systematic review of theoretical analysis, providing a scientific basis and technical support for the optimal design and construction of concrete materials. Additionally, this paper will primarily discuss the mechanisms of concrete drying shrinkage and the current research on the drying shrinkage of machine-made sand concrete, providing references and guidance for engineering practice.

2. BASIC CONCEPTS OF CONCRETE SHRINKAGE

The phenomenon of concrete undergoing volume reduction due to factors such as changes in water content, chemical reactions, and temperature decreases is collectively referred to as concrete shrinkage. It is a deformation that is independent of load and related to time, mainly including plastic shrinkage, thermal shrinkage, carbonation shrinkage, drying shrinkage, and autogenous shrinkage (Huang and Hui 1990).

2.1 Plastic Shrinkage

Plastic shrinkage of concrete refers to the volume change that occurs in freshly poured concrete before it hardens. Plastic shrinkage typically occurs during the construction process, especially within 3 to 12 hours after concrete pouring (Dai 2019). During this period, the cement hydration reaction is intense, molecular chains are gradually formed, and there is bleeding and rapid evaporation of water within the concrete, leading to water loss and shrinkage. Additionally, as aggregates sink due to their own weight and the concrete has not fully hardened, this type of shrinkage is termed plastic shrinkage (Dai 2019).

Plastic shrinkage is related to the composition of concrete materials, external environmental conditions, and construction techniques. Specifically, factors such as high cement content, high water-cement ratio, large exposed surface area, low environmental humidity, and high wind speed can all contribute to increased plastic shrinkage in concrete.

When plastic shrinkage is constrained by external factors (such as formwork, steel reinforcement, or other concrete components), tensile stresses are generated within the concrete, which may lead to uneven stress distribution within the concrete structure and stress concentration in certain areas. Over time, this uneven stress distribution can further exacerbate deformation and damage to the concrete structure, affecting the overall stability of the structure.

To mitigate plastic shrinkage, it is important to ensure that the concrete is vibrated uniformly and compactly, avoiding over-vibration or insufficient vibration. Additionally, the support and stability of the formwork should be enhanced to prevent swelling or settlement. Measures such as covering the concrete surface with plastic film or spraying a curing agent before initial setting should be taken to maintain the necessary humidity on the concrete surface and prevent excessive water evaporation that can cause plastic shrinkage. The curing time should be sufficient to ensure that the concrete fully hardens and reaches the designed strength.

2.2 Thermal Shrinkage

Concrete thermal shrinkage, also known as cold shrinkage, is the deformation that occurs in concrete due to temperature decrease (above 0°C) during its setting, hardening, and use. After the pouring of concrete, the hydration reaction of cement releases heat, causing the internal temperature of the concrete to rise. As the hydration reaction progresses, the heat gradually dissipates, leading to a decrease in internal temperature and subsequent volume reduction, which is known as temperature shrinkage. When the external ambient temperature is low, the surface of the concrete cools rapidly and shrinks, while the interior remains at a higher temperature due to the heat of hydration, resulting in temperature differences and differential shrinkage between the interior and exterior. For mass concrete, cracks are primarily caused by temperature shrinkage (Gao et al., 2024).

Proper curing conditions are crucial for controlling concrete thermal shrinkage. Adequate curing can slow down the evaporation rate of water from the concrete surface, reduce temperature gradients and shrinkage differences, and thereby minimize crack formation. In design, it is advisable to prioritize the use of cement types with low hydration heat and low shrinkage, such as moderate heat cement or low heat cement. These cement types release less heat during the hardening process, reducing the temperature stresses within the concrete and thus decreasing thermal shrinkage.

2.3 Carbonation Shrinkage

Concrete carbonation shrinkage refers to the phenomenon of volume reduction that occurs when carbon dioxide (CO_2) in the atmosphere reacts with the hydration products of cement in the presence of moisture (actually, the true mediator is carbonic acid), producing calcium carbonate ($CaCO_3$) and free water, among other products. Carbonation shrinkage primarily arises from the chemical reactions between CO_2 and the hydration products of cement. These reactions include the reaction of $Ca(OH)_2$ with CO_2 to form $CaCO_3$, which leads to volume contraction. Additionally, the carbonation of $Ca(OH)_2$ reduces the alkalinity of the cement paste, causing other originally stable hydration products to also undergo carbonation reactions, further exacerbating volume contraction.

Dense concrete structures can slow down the diffusion rate of CO_2, thereby reducing the rate of carbonation. A moderate humidity level (approximately 50%) favors the carbonation process (Ren 2020). Excessively high humidity fills the pores of the concrete with water, hindering the diffusion of CO_2. Conversely, excessively low humidity results in insufficient water in the pores for CO_2 to form carbonic acid, making carbonation less likely to occur.

2.4 Drying Shrinkage

Drying shrinkage of concrete refers to the irreversible deformation that occurs when concrete, after cessation of curing, loses its adsorbed water within the internal capillary and gel pores when exposed to unsaturated air. This type of shrinkage is caused by the migration of water within the concrete and pore characteristics, and it is one of the main factors influencing concrete shrinkage.

A higher water-cement ratio results in greater drying shrinkage of concrete. Additionally, the content and type of aggregates also affect drying shrinkage. A higher aggregate content leads to less drying shrinkage, and different types of aggregates have varying effects on drying shrinkage. Aggregates with good grading or increased maximum particle size have lower porosity, which reduces the drying shrinkage of concrete. Relative humidity has a significant impact on the drying shrinkage of concrete. In environments with lower relative humidity, the evaporation rate of water from the concrete surface increases, leading to greater drying shrinkage (Man 2023).

The volume of cement hydration products is smaller than the total volume of cement and water before the reaction, which is one of the main reasons for volume shrinkage in concrete. Different types of cement have different hydration reaction characteristics and products, which have varying effects on the drying shrinkage of concrete. For pure Portland cement, the shrinkage of cement paste mainly depends on the content of tricalcium aluminate (C3A), sulfur trioxide (SO3), gypsum, and cement fineness. Generally, shrinkage increases with the content of C3A mineral components, and cement with finer particle size and insufficient gypsum content also exhibits greater shrinkage.

2.5 Autogenous Shrinkage

Autogenous shrinkage of concrete refers to the self-volume deformation that occurs due to the consumption of water during cement hydration under sealed conditions (without moisture exchange with the outside environment). During this process, the consumption of water during cement hydration causes the liquid level in the gel pores to drop, forming a meniscus, which produces the so-called self-drying effect. This leads to a decrease in the relative humidity of the concrete and a reduction in volume (Jiang et al., 2001, Li et al., 2000).

The water-cement ratio has a significant impact on autogenous shrinkage of concrete. When the water-cement ratio is less than 0.35, the relative humidity of the concrete quickly drops below 80%, at which point autogenous shrinkage and drying shrinkage contribute almost equally (He et al., 2022). As the water-cement ratio decreases, autogenous shrinkage becomes more pronounced. The elastic modulus, particle size, and content of aggregates also have an impact on autogenous shrinkage. A higher aggregate content and elastic modulus result in less autogenous shrinkage. Aggregates serve as the skeleton of concrete, restricting autogenous shrinkage. Aggregate grading, maximum particle size, ratio of coarse to fine aggregates, and aggregate volume fraction in concrete all affect autogenous shrinkage. Curing conditions also have an impact on autogenous shrinkage. Timely and adequate curing can accelerate cement hydration, but even if water is replenished during curing, autogenous shrinkage may still occur because external water is not easily permeable into the concrete (He et al., 2022).

Autogenous shrinkage is a special case of drying shrinkage, but they are comparable in magnitude. Autogenous shrinkage mainly occurs in the initial stages after concrete mixing, so most or even all of the autogenous shrinkage of concrete may have already occurred before formwork removal.

3. MECHANISMS OF DRYING SHRINKAGE IN CONCRETE

Drying shrinkage, as the primary type of shrinkage deformation affecting the volume stability of concrete, accounts for approximately 80% of the total shrinkage deformation in concrete, making it highly representative in the observation and study of volume stability (Man 2023)**Error! Reference source not found.**. Concrete operating in a dry environment is prone to drying shrinkage and other shrinkage deformations due to rapid water evaporation rates. Furthermore, for manufactured sand concrete, due to the presence of its own stone powder, internal chemical reaction phenomena such as rapid and concentrated early hydration reactions are observed in practical applications. Therefore, under the coupling effects of the above multiple factors, the drying shrinkage performance of manufactured sand concrete is a continuous and severe challenge (Man 2023).

The analysis of microscopic mechanisms has laid a solid foundation for in-depth research on the drying shrinkage of concrete. Currently, the following four theories are generally accepted regarding the mechanisms that cause drying shrinkage in concrete:

3.1 Capillary Tension Theory

The capillary tension theory, as a fundamental theory in micromechanics, has been a general explanation for the study of drying shrinkage in concrete. It suggests that drying shrinkage in concrete occurs due to capillary tension arising from partially saturated capillary pores formed within the concrete after the cement hydration reaction, especially when the relative humidity inside the matrix exceeds 45% (Wang et al., 2018). Research generally agrees that drying shrinkage is related to changes in the meniscus of water in capillaries during the drying process. As concrete is exposed to a dry environment for an extended period, internal moisture continuously escapes into the surrounding environment, generating an increasingly negative pressure on the capillary walls. Meanwhile, as the relative humidity changes, the vapor pressure above the concave meniscus of the capillary pores also increases. Under the combined action of these forces, capillary water tension increases to maintain internal liquid-level equilibrium, leading to continuous compression of the cement paste in the concrete and resulting in macroscopic volume shrinkage deformation.

3.2 Disjoining Pressure Theory

This theory proposes that when the gap between the surfaces of adjacent particles within the paste reaches a certain distance, the water adsorbed on the surfaces of the solid particles generates an attractive force, known as disjoining pressure. When the adsorbed water within the concrete evaporates and escapes in a dry environment, it causes a decrease in the relative humidity between the particles. Studies have shown that when the relative humidity of the interlayer water is less than 35%, the disjoining pressure at this point will be smaller than the van der Waals force (Wang et al., 2018). Consequently, the gaps between the gel particles decrease, and the particles pack more tightly together, leading to the occurrence of drying shrinkage.

3.3 Surface Tension Theory of Solid Surfaces

This theory suggests that the drying shrinkage of concrete is caused by the surface tension generated by the water adsorbed on the surfaces of internal gel particles. Specifically, due to differences in the binding forces among water molecules on the particle surfaces, the energy on the particle surfaces is higher than that inside, resulting in surface tension. The surface tension of cement particles in cement paste is related to the relative humidity. Research (Peng and Chen 2017) indicates that a relative humidity of 45% serves as a critical point. When the ambient humidity is above 45%, a large number of water molecules are adsorbed on the surfaces of cement particles, and the surface tension generated between particles is negligible. However, when the humidity of the environment in which the concrete is placed is below the critical value of 45%, to maintain hydrostatic pressure equilibrium inside and outside the particles, the surface tension gradually increases as water evaporates, causing the particles to decrease in volume and resulting in drying shrinkage of the concrete (Peng and Chen 2017).

3.4 Interlayer Water Loss Theory

This theory proposes that the hydrated cement product, C-S-H (Calcium-Silicate-Hydrate) gel, inherently possesses a layered structure. A reduction in the relative humidity within the concrete creates an energy gradient with the external environment, forcing interlayer water to migrate outwardly. Ultimately, this leads to macroscopic and microscopic shrinkage deformation of the concrete. This theory is generally recognized as a primary factor influencing the drying shrinkage of concrete. It is universally believed that interlayer water migration and irreversible shrinkage deformation occur only when the relative humidity is less than 11% (Li 2015).

Under such conditions, the interlayer water within the C-S-H gel structure is lost due to drying, causing the gel layers to contract and leading to a reduction in the overall volume of the concrete. This phenomenon is particularly significant in environments with extremely low humidity, where the loss of interlayer water contributes significantly to the drying shrinkage of concrete.

3.5 Analysis of Differences Between Various Theories

The capillary tension theory focuses on the tension generated by the evaporation of water in the capillaries within the concrete. When the environmental is below 100%, the water in the capillary pores evaporates, forming a concave liquid surface, creating surface tension that exerts pressure on pore walls, leading to concrete shrinkage. The disjoining pressure theory concerns the pressure generated by water adsorbed on the surface of the gel. As the changes, the disjoining pressure also changes; when the disjoining pressure is less than the van der Waals force, particles aggregate, leading to a reduction in volume of the concrete. The solid surface tension theory emphasizes the rapid increase in surface tension when adsorbed water is removed from the cement gel, which compresses gel particles and causes the concrete to shrink. The interlayer water loss theory mainly describes the shrinkage phenomenon caused by the loss of water from the concrete to the, focusing on the impact of water loss on the volume of the concrete.

4. RESEARCH STATUS OF DRYING SHRINKAGE OF MANUFACTURED SAND CONCRETE

Mechanism sand, as a type of artificial sand processed by humans, extensively utilizes various rock resources in its manufacturing process, offering diverse sources and relatively costs. It is processed through advanced crushing and screening technologies, effectively replacing natural sand. In comparison, mechanism sand not only boasts abundant resources and economic costs, but shows significant advantages in environmental protection. Its production process emphasizes energy conservation and emission reduction, reducing the exploitation and destruction of natural resources. Meanwhile, by recycling waste materials it achieves sustainable use of resources, demonstrating high environmental sustainability.

Research on manufactured sand aids in optimizing its production processes, improving product quality, meeting the demand for sand materials in construction projects, while reducing the exploitation of natural resources and promoting green and sustainable development in the construction industry. Its application in construction projects is becoming increasingly widespread. However, there are differences between the characteristics of manufactured sand and natural sand, leading to variations in the properties of their respective concretes. Fig. 1 shows the 90-day shrinkage of different strength grade concrete with manufactured sand and natural sand.

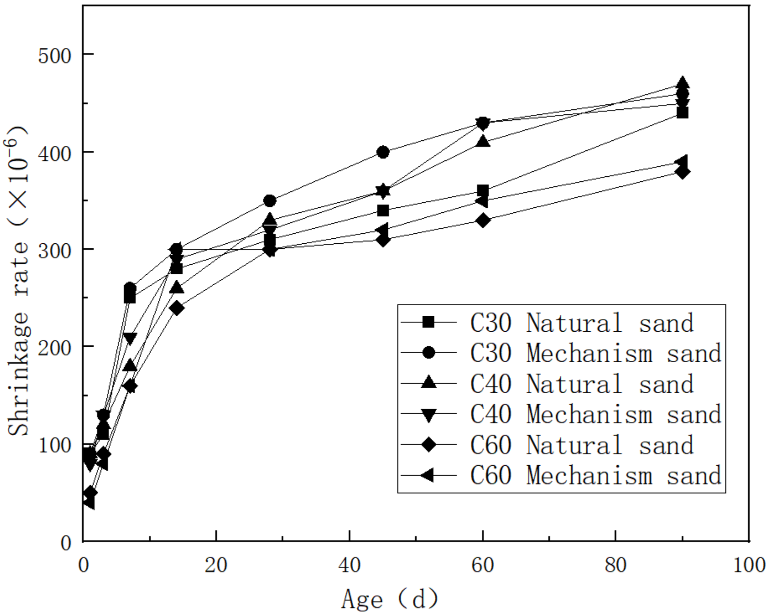

Fig. 1. Shrinkage of concrete with different strength grades of manufactured sand

Drying shrinkage is a significant deformation property of manufactured sand concrete after pouring, which directly affects the durability and crack resistance of the concrete. By studying the drying shrinkage of manufactured sand concrete, we can gain a deeper understanding of its shrinkage mechanism and influencing factors, thereby optimizing the concrete mix proportions and enhancing the overall performance of the concrete. Furthermore, studying the drying shrinkage of manufactured sand concrete can further promote the application of manufactured sand and provide technical support for the widespread use of manufactured sand concrete in construction projects.

The primary difference between manufactured sand and natural sand lies in their stone powder content. This section focuses on the impact of stone powder content on the drying shrinkage of manufactured sand concrete.

Malhotra V.M. (1985) and others found that limestone powder content always benefits the adhesive properties of concrete. Within the range of 0 to 20% incorporation, the drying shrinkage rate increases with the increase of stone powder content, and beyond 10%, the influence of the water-cement ratio becomes greater than that of the stone powder content. Ma et al. (2022) explored the shrinkage properties of different manufactured sand mortars and found that the manufactured sand mortar made from natural stone has lower drying shrinkage values than that made from recycled aggregates. Li Meili et al. (2001) conducted experiments on manufactured sand concrete with stone powder contents of 0%, 5%, and 10%. Their research on the shrinkage of manufactured sand concrete revealed that when the stone powder content does not exceed 10%, the shrinkage is hardly affected by the stone powder content.

Wang Jiliang (2008) studied and concluded that an increase in the MB value of manufactured sand has a significant impact on the drying shrinkage of concrete, especially on its early-age shrinkage. When the MB value of manufactured sand is less than or equal to 1.10, there is basically no effect on the drying shrinkage rate of concrete at 1d and 3d, with a slight increase in the drying shrinkage rate at 5d and beyond. However, when the MB value is greater than or equal to 1.45, there is a noticeable increase in the drying shrinkage rate of concrete, both in the early and later stages, especially in the early stages. When the MB value is greater than or equal to 2.15, the drying shrinkage rates of concrete at 1d and 3d increase by 20% and more than 20% respectively compared to the control, while the ultimate drying shrinkage rate of the concrete increases by more than 8.8%.

Li Beixing et al. (2009) studied the impact of the methylene blue (MB) value on shrinkage and found that the presence of clay increases the plastic shrinkage of the concrete surface. Additionally, the drying shrinkage rate of concrete increases as the MB value rises. With an increasing MB value, especially when it is ≥1.45, there is a notable increase in the drying shrinkage rate of concrete, both in the early and later stages. The main reason for this is that clay particles, which have a porous layered structure, adsorb a large amount of mixing water and swell when dispersed in concrete. Once the concrete is exposed to a dry environment, as surface water continuously evaporates and is lost, water migrates from the interior of the concrete to the exterior, reducing the internal relative humidity. The water originally adsorbed in the pores of clay particles is released due to diffusion. Furthermore, the presence of clay in manufactured sand, with its large specific surface area, increases the volume content of the paste to a certain extent. Both of these factors contribute to an increase in the degree of drying shrinkage of the concrete.

Hu Bing et al. (2010) reached a similar conclusion in their research. The drying shrinkage rate of mortar increases with an increase in the mud and fine powder content of manufactured sand, particularly affecting early-age drying shrinkage more significantly. Experimental studies were conducted to investigate the impact of different mud and fine powder contents (0%, 1%, 3%, 5%, and 7%) on the drying shrinkage of mortar. The results showed that as the mud and fine powder content increases, the drying shrinkage value of the mortar also increases, and the drying shrinkage values of all mortar mixes increase with age. The reason for the increase in shrinkage due to mud and fine powder is that the mud and fine powder contained in the mortar are non-reactive substances with very fine particles that adsorb a large amount of water. These non-reactive substances weaken the bond between the cement paste and the aggregates in the interface zone, affecting the adhesion between the paste and the aggregates and reducing the aggregates' ability to inhibit shrinkage. On the other hand, the water adsorbed by them is free water that is easily volatile. After evaporation, their deformation is significant, leading to a more pronounced increase in the drying shrinkage value of mortar with a higher mud and fine powder content compared to mortar with a lower content. Further analysis revealed that at 3 days, the drying shrinkage value of mortar with a mud and fine powder content of 7% increased by up to 64% compared to mortar with a mud and fine powder content of 0%, by 43.9% at 7 days, and by only 28% at 90 days. It can be seen that mud and fine powder have a more significant impact on the early-age drying shrinkage value of mortar.

Yang Haicheng et al. (2021) studied the impact of granite powder on the performance of C80 high-performance concrete and found that the drying shrinkage rate of manufactured sand concrete is comparable to that of river sand concrete when the granite powder content does not exceed 4.5%. However, when the granite powder content exceeds 6.5%, the drying shrinkage rate increases significantly. As the granite powder content in manufactured sand increases, the drying shrinkage values of high-strength, high-performance concrete at different ages generally show an increasing trend. Specifically, when the granite powder content increases from 3.0% to 6.5%, the 60-day drying shrinkage value of manufactured sand high-strength, high-performance concrete increases from 246×10-6, although the increase is not significant. However, when the granite powder content increases from 6.5% to 8.5%, the 60-day drying shrinkage value of high-strength manufactured sand concrete increases from 264×10-6, indicating a significant increase in the drying shrinkage value of the concrete. Therefore, to reduce the drying shrinkage of C80 high-strength manufactured sand concrete, the granite powder content in manufactured sand should not exceed 6.5%. Additionally, compared to concrete made with river sand, when the granite powder content in manufactured sand does not exceed 4.5%, the drying shrinkage value of high-strength manufactured sand concrete is comparable to that of river sand concrete. An appropriate amount of granite powder can optimize the particle distribution of the concrete paste, serving as a micro-aggregate filler, thereby improving the compactness of the concrete and benefiting the reduction of shrinkage deformation in high-strength concrete. However, excessive granite powder content in manufactured sand will increase the proportion of paste in the concrete, thus increasing the drying shrinkage deformation.

Wei Yuanyuan et al. (2021) studied the shrinkage properties of manufactured sand concrete and found that the total shrinkage value is greater than that of river sand concrete. The shrinkage values of manufactured sand concrete and river sand concrete at the same mix proportions within 90 days were compared. Both types of concrete exhibited increasing shrinkage values as the age increased. Even after 90 days, the shrinkage values continued to increase. Overall, the total shrinkage of manufactured sand concrete is significantly greater than that of river sand concrete. The high content of granite powder in manufactured sand concrete, with small particle sizes, has a significant adsorption effect on pore fluid in the concrete matrix, reducing the internal relative humidity of the concrete and increasing capillary pressure, ultimately leading to increased autogenous shrinkage in manufactured sand concrete.

Imamoto et al. (2007) studied the impact of aggregate specific surface area on the drying shrinkage of concrete and concluded that the larger the specific surface area of the aggregate, the greater the drying shrinkage rate. The specific surface area of aggregates generally increases as the particle size decreases, consistent with Imamoto's findings. Li Jiazheng et al. pointed out in their research that as the maximum particle size of aggregates decreases, the drying shrinkage rate of ECC gradually increases. Adesina et al. (2021) studied the shrinkage properties of ECC prepared with waste glass replacing quartz sand and found that glass sand can reduce the shrinkage rate, and 2.0 vol% of PVA fibers can prevent plastic shrinkage cracks.

Li Qian et al. (2016) investigated the impact of slag powder and fly ash on the early-age shrinkage properties of manufactured sand concrete and found that adding slag powder alone increases early-age shrinkage, and the shrinkage rate gradually increases with age. Adding fly ash alone is better than adding a blend of fly ash and slag powder in terms of early-age shrinkage. Concrete with single additions of Class I fly ash, ground slag powder, or a blend of both exhibits varying degrees of shrinkage, and the shrinkage rate increases with age. Concrete with 30% single addition of ground slag powder exhibits greater shrinkage at all ages compared to concrete with 30% fly ash, with 28-day shrinkage rates of 373×10-6, respectively. When 20% fly ash is blended with 10% ground slag powder, the early-age shrinkage (3 days) of the concrete is reduced compared to single additions, but the later-age shrinkage increases significantly, with the 28-day shrinkage falling between that of single additions of fly ash and ground slag powder. This is because blending fly ash and ground slag powder improves the particle size distribution of the cementitious materials, making the system more dense and reducing the evaporable water content, which makes water evaporation more difficult and delays the early-age shrinkage rate of the concrete. However, as the curing age increases, the pozzolanic effect of ground slag powder enhances, and its hydration products gradually refine the pores, increasing the capillary negative pressure effect and significantly increasing the later-age shrinkage of the concrete.

The shrinkage of concrete is a complex phenomenon involving the interplay of various factors. In addition to common factors such as cement hydration reactions water-cement ratios, and curing conditions, the microstructure of the material, porosity, type, and size of aggregates are also important alternative factors influencing concreteage. The microstructure of concrete, especially the structure and morphology of cement hydration products, has a significant impact on the shrinkage behavior of concrete. For instance the morphology and quantity of calcium hydroxide ($Ca(OH)_2$) crystals formed during cement hydration can affect the shrinkage rate of concrete. When these undergo carbonation to form calcium carbonate ($CaCO_3$) precipitates, it can lead to carbonation shrinkage. Changes in the microstructure, such as distribution and connectivity of pores, can also influence concrete shrinkage. The higher the porosity, the greater the potential for concrete shrinkage, as the evaporation water from the pores can lead to a reduction in volume. These factors do not act in isolation but interact with each other to jointly influence the shrinkage behavior of. For example, there is an interaction between porosity and the type of aggregate. The size and distribution of aggregates can affect the connectivity and distribution of pores, influencing the shrinkage of concrete.

5. CONCLUSION

This paper mainly conducts research and analysis on the types of concrete shrinkage, the mechanism of drying shrinkage, and the factors influencing the drying shrinkage of manufactured-sand concrete. The main conclusions are as follows:

Concrete shrinkage is a complex phenomenon essentially characterized by volume reduction resulting from a combination of factors, including but not limited to water content changes, chemical reactions, and temperature decreases. Specifically, the types of concrete shrinkage include plastic shrinkage, temperature shrinkage, carbonation shrinkage, drying shrinkage, and autogenous shrinkage. These types of shrinkage are closely related to the passage of time and are independent of external loads. Plastic shrinkage is particularly significant in the initial stage after concrete pouring, influenced by factors such as material composition, external environmental conditions, and construction techniques. Temperature shrinkage arises from temperature differences between the interior and exterior of concrete, which is particularly evident in mass concrete. Carbonation shrinkage is the result of reactions between concrete and carbon dioxide in the air, while drying shrinkage is caused by the loss of internal moisture in concrete. Autogenous shrinkage is a special type of shrinkage that occurs under sealed conditions due to volume deformation resulting from the consumption of water during cement hydration.

Drying shrinkage plays a decisive role in the volume stability of concrete. To gain a deeper understanding of this phenomenon, researchers have proposed various theories to explain its mechanism, including capillary tension theory, disjoining pressure theory, solid surface tension theory, and interlayer water loss theory. These theories reveal the volume shrinkage caused by the loss of internal moisture in concrete at the microscopic level, providing a solid theoretical foundation for in-depth studies on the drying shrinkage behavior of concrete.

Manufactured sand, as a widely used substitute for natural sand, plays an important role in construction engineering. However, compared with natural sand concrete, the drying shrinkage performance of manufactured sand concrete exhibits certain differences. Specifically, factors such as stone powder content, MB value (an indicator representing the content of mud and clay substances in manufactured sand), and clay content have significant impacts on the drying shrinkage of manufactured sand concrete. Studies have shown that an appropriate amount of stone powder can optimize concrete performance, but excessive stone powder will lead to increased drying shrinkage. Furthermore, the total shrinkage of manufactured sand concrete is usually greater than that of river sand concrete, which may be related to the adsorption effect of stone powder particles and the specific surface area of aggregates. Therefore, in the application of manufactured sand concrete, it is necessary to reasonably control the stone powder content and optimize the concrete mix proportions to reduce drying shrinkage and thereby improve the overall performance of concrete.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/126743