

Exploring Current Techniques for Improving the Properties of New Concrete

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Abstract. In modern construction, the properties of new concrete are crucial for building quality and structural performance. Recent technological advancements have led to significant progress in enhancing the properties of new concrete. This study employs theoretical and experimental methods to explore the connection among shear stress and shear strain rate under vibration, the impact of aggregate substitution on concrete performance, and the rheological properties of moist shotcrete. The findings suggest that adjusting mix proportions and using additives can significantly improve concrete's strength, durability, and workability. This research provides engineers with a theoretical foundation for optimizing concrete mixtures and construction techniques, thereby improving overall building quality and construction efficiency. The findings suggest that sustainable materials can be used without compromising structural integrity, making the construction process more environmentally friendly while maintaining high performance standards. Furthermore, this study highlights the importance of understanding concrete behavior under various conditions to develop more resilient and long-lasting structures.

Keywords: Concrete properties, Aggregate substitution, Rheological properties.

1. Introduction

In modern construction projects, the properties of new concrete are important for the quality of construction and the structural performance of buildings. Today, concrete is widely used in various construction projects, but its working properties, strength development and durability in the new state are still hot topics for research. Recent advancements in technology have significantly contributed to the progress made in enhancing the qualities of new concrete.

Several theoretical and experimental studies have been conducted to address these challenges and improve the performance of new concrete in various applications. Under vibration conditions, the connection among shear stress and shear strain rate of new concrete was investigated utilizing the motion reduction theory and Eyring rate process theory [1]. These theories are crucial as they provide insights into the behavior of concrete under dynamic conditions, which is essential for ensuring the stability and longevity of structures subject to vibrations, such as bridges and high-rise buildings. By understanding these relationships, engineers can design concrete mixes that maintain their integrity and performance under such conditions. Mehran Shirani Bidabadi et al. substituted natural fine particles and coarse particles with recycled fine particles and coarse particles to varying degrees [2]. The findings demonstrated that the anticipated concrete performance was not considerably affected by the substitution of 30% of fine aggregate. This finding is significant as it suggests that high-performance concrete can be achieved using more sustainable materials, reducing the environmental impact of construction projects without compromising structural integrity. In their 2021 study, Hou et al. examined how moisture conditions and the amount of recycled brick aggregate (RBA) affect the rheological qualities of recycled concrete (RAC). [3]. This discovery has an important implication for the application of sustainable building materials. The researchers conducted a thorough analysis of the practical aspects of the empirical parameters, such as slump and slump flow, within 45 minutes after mixing. They also examined the rheological parameters, including dynamic yield stress, plastic viscosity, and static yield stress. Gang Pan (2019) conducted an investigation on the rebound rate of wet shotcrete and the rheological parameters of new concrete, which encompassed slump, yield stress,

and plastic viscosity [4]. Additionally, the connection among sandblasting rebound and energy dissipation was investigated by incorporating varying types and dosages of additives. Furthermore, Zhisong Xu (2021) utilised a completely Moving Particle Semi-implicit (I-MPS) technique and the Discrete Particle Multiple Phase (DPMP) model to replicate the flow of high-fluidity concrete in two different L-box configurations. [5]. He verified that the suggested numerical technique is capable of simultaneously simulating the flow and segregation characteristics of new concrete, this simulation capability is critical for predicting the performance of high-fluidity concrete in practical applications, ensuring that the concrete can flow and settle properly without segregation, leading to more uniform and durable structures.

This paper aims to explore various methods to optimize the properties of new concrete, thereby improving building quality and construction efficiency. Specifically analyzes aspects such as material selection, mix proportion adjustments, additive applications, and construction technique improvements to enhance the general efficiency of new concrete.

2. Performance and improvement of new concrete

Regardless of the casting process used, ensuring the workability of new concrete on a building site is crucial. Nevertheless, the concrete consistency may vary when new concrete is placed. High viscosity concrete can make the pouring process more difficult, possibly leading to construction delays or quality issues, thus, workers may demand compensation for construction difficulties, and the supervisor may overlook the seriousness of the situation. Conversely, when the viscosity is low, the worker can enhance the fluidity of the concrete for vibration or pouring by adding water to the concrete mixing tank [6]. Although the approach can temporarily improve fluidity of concrete, this situation significantly impacted the workability, often resulting in stratification, water seepage, and even segregation. Therefore, adequate measures must be implemented at the building site to prevent improper casting procedures.

2.1. New concrete workability

Segregation and bleeding are the primary indications of inadequate workability in fresh concrete. When new concrete is formed, structures naturally tend to separate because of variations in particle size and the specific gravity of the materials used. Segregation is defined as the process in which there is a noticeable inclination for the larger and smaller particles in a mixture to separate from each other. Typically, as the mixture's viscosity worsens, the segregation tendency increases. Efforts should be made to minimize the segregation of concrete [7]. High motion of concrete in shipping and significant decrease in fluid level while pouring can result in discrimination, resulting in surface imperfections such as sandy streaks, porosity layers, and hexagonal pits. These attributes can have a negative impact on the robustness and longevity of fresh concrete.

During the process of compacting concrete, solid particles have a natural inclination to go downward, which is influenced by their specific gravity and dimension [8]. If the viscosity of the mixture is not enough to keep all of the liquid in place, some of the water may slowly migrate and rise towards the surface, while another portion of the liquid may seep through the joint in the formwork. This type of division is commonly known as hemorrhage. In order to efficiently decrease bleeding, it is essential to employ appropriate additives and minimize the magnitude of concrete vibration. Moreover, the choice of cement type is of great significance, and aeration offers an additional highly effective method for controlling bleeding. A commonly employed technique to guarantee the ideal workability of concrete throughout the pouring process is to increase the initial water content or prolong the mixing of the concrete prior to its discharge.

2.2. Materials and Additives

As the quantity of mud grows, the fluidity of the mixture increases, provided that a specified water-cement ratio is maintained. Excessive cement slurry leads to a decrease in aggregate content, causing

slurry flow and reducing the stability, strength, and durability of the mixture. Additionally, the aggregate's surface is not properly coated, and its gaps are not filled. The maximum particle size, gradation, and form of the aggregate have an impact on the surface area of the aggregate. The workability of the material declines while the specific surface area increases due to the need for a larger amount of the slurry to come into contact with the aggregate particles [9]. Therefore, a reduced quantity of slurry is implemented to facilitate lubrication. Workability will rise when the maximum particle size of the aggregate grows, the aggregate particles become spherical, or the combined gradient becomes coarser. As a result, other conditions remain constant.

In order to satisfy the water consumption standard, various types of cement are employed. Ordinary concrete cement mixtures are typically more effective than slag cement and pozzolanic cement. Without increasing the consumption of water or cement, the workability of the concrete mixture can be significantly enhanced by the addition of certain admixtures [10]. Water-reducing agents and aerating agents are the primary admixtures that enhance the workability of concrete. The degree of workability improvement depends on the conventional characteristics of new concrete and the type and quantity of admixtures used.

Changes in the water-cement ratio significantly impact the strength of low-strength grade concrete; as the ratio decreases, the concrete's strength increases. Additionally, the utilization of slag powder and fly ash into the concrete mix plays a crucial role in enhancing its properties. Slag powder and fly ash contribute to the pozzolanic reaction, which further densifies the concrete matrix and improves its overall durability and strength. These supplementary cementitious materials help reduce the permeability of concrete, increase its resistance to chemical attacks, and improve its long-term performance. A portion of slag powder and fly ash is typically incorporated into the engineering application of concrete. Fine aggregate particles are introduced into the coarse aggregate as a consequence of mechanical fracture induced by cracks during the hydration hardening process [11]. Cement and the secondary hydration reaction fill the pores between the coarse aggregate, resulting in a much denser concrete. Utilizing fly ash and slag powder improves the mechanical qualities of concrete and promotes sustainability by making use of industrial by-products.

2.3. Environmental factors

Both humidity and temperature are environmental elements that might adversely affect the performance of newly formed concrete. The change in workability of a specific type of concrete is determined by the speed at which cement hydrates and water evaporates. As the temperature increases, the evaporation rate of moisture in the concrete mixture accelerates, resulting in reduced fluidity. Insufficient agitation time can negatively impact the performance of concrete, resulting in a worse-quality mix [12]. Consequently, the minimum duration for mixing is established at 3 minutes, along with the specified distance between the mixer and the pouring location. Additionally, on-site processes necessitate a comprehensive set of management techniques.

3. Challenges and prospects

While significant advancements have been made in enhancing the performance of new concrete, several challenges remain. Addressing these challenges is essential to further improve concrete quality, durability, and sustainability in modern construction.

One of the main challenges in concrete technology is achieving a balance between strength and durability. The implementation of nanomaterials, including carbon nanotubes, nano-silica and nano-titanium dioxide, has shown promise in enhancing concrete's mechanical properties and durability. Nanomaterials can fill the micro-pores in the concrete matrix, leading to a denser and more impermeable structure. However, the high cost and potential health risks associated with producing and handling nanomaterials pose significant challenges. Further research is needed to optimize the use of nanomaterials in concrete and develop cost-effective production methods [13].

Self-healing concrete is another innovative approach that has gained attention in recent years. This type of concrete can autonomously repair cracks and restore its structural integrity, significantly extending the lifespan of concrete structures. The self-healing mechanism can be activated by incorporating microcapsules containing healing agents or using bacteria that precipitate calcium carbonate to seal cracks. Despite its potential, the implementation of self-healing concrete in large-scale construction faces challenges, including the high cost of materials and the need for reliable activation mechanisms under varying environmental conditions [14].

Sustainable concrete materials are critical for reducing the environmental impact of construction. Utilizing industrial by-products, such as fly ash, slag, and silica fume, as substitutes for cement in concrete manufacturing can greatly diminish the environmental impact by reducing its carbon footprint. Additionally, developing alternative binders, such as geopolymer concrete, offers a promising route towards more sustainable construction practices. However, the variability in the quality of these materials and the lack of standardized testing methods remain significant barriers to their widespread adoption [15].

Future advancements in digital technologies, such as 3D printing and Building Information Modeling (BIM), are expected to revolutionize concrete construction. 3D printing can enable the precise placement of concrete and create complex geometries that are difficult to achieve with traditional methods. BIM can optimize concrete mix designs and construction processes, leading to more efficient and sustainable practices.

4. Conclusion

The study explores methods to enhance new concrete properties, improving construction quality and efficiency. Freshly poured concrete will undergo a sequence of procedures including transportation, pumping, and compaction, significantly influencing its performance and eventual hardening while also causing substantial changes in its strength and durability. Based on the literature summary and analysis provided above, it is evident that the efficiency of new concrete is primarily influenced by environmental factors, mixing ratio and raw materials. To enhance the new concrete performance, the following measures can be adopted: adjusting the composition of concrete, ensuring the strength, durability, and economy, and making appropriate adjustments to the proportion of concrete to improve workability. Incorporate a diverse range of admixtures into the concrete mixture to minimize the occurrence of segregation and bleeding phenomena while maintaining the desired characteristics of the concrete. Enhance the efficacy of vibrating machinery to fulfill the specifications of the concrete mixture. To mitigate the impact of natural elements, it is advisable to minimize building activities during the rainy season and regulate the effect of surrounding climate on the absorption of moisture in the mixture.

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