SHRINKAGE PROPERTIES OF CEMENT CONCRETE INCORPORATED WITH DIFFERENT SUPPLEMENTARY CEMENTITIOUS MATERIALS-A Review

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Abstract -*Through its lifespan, concrete undergoes several physical and chemical changes, which normally led to shrinkage of concrete, especially at an early age, when the initial hydration processes take place. The shrinkage of concrete at an early stage of hardening may lead to the initial formation of cracks that vary in shape and size and depends on the concrete constituents and surrounding conditions, including temperature and/or the moisture state that may lead to volumetric deformation Many studies have shown that the total prevention of concrete from undergoing shrinkage is impractical. However, different practices have been used to control various types of shrinkage in concrete and limit its magnitude. This paper provides the shrinkage behavior of cement concrete incorporated with different mineral admixtures and fibers.*

Key Words: Plastic Shrinkage, Autogenous Shrinkage, Drying Shrinkage, Fly ash, silica fume

1. INTRODUCTION

Concrete experiences a number of physical and chemical changes during the course of its lifetime, which often cause concrete to shrink, particularly when it is young and the first hydration processes are still taking place. Based on the components of the concrete and the environment, including temperature and/or moisture levels that may cause volumetric deformation, the shrinkage of concrete during the early stages of hardening may result in the initial creation of cracks that vary in shape and size. Due to the imposed force on concrete particles, shrinkage cracking forms while the concrete is still in the plastic condition and persists through the hardened stage. These stresses are brought on by the consumption of the water used to make the cement paste, which occurs after the water present in the pores is lost. It is almost certain that the concrete texture will shrink and develop cracks.

In brittle materials, cracks often appear when the tensile stress exceeds the rapture strength. It is challenging to isolate the effect of each component separately, however, due to the interaction of the elements and parameters determining the emergence and spread of cracks in concrete. The development of thermal stresses, creep, and crack formation could be some of the key nonlinear phenomena that control the shrinking behaviour of young concrete.

These issues with producing conventional concrete resulted in a greater demand for nonconventional concretes that perform better in terms of strength as well as a more resilient mixture that offers better shrinkage resistance. The behaviour of concrete's shrinkage and the governing factors affecting its various types of shrinkage, including chemical shrinkage, plastic shrinkage, drying shrinkage, carbonation shrinkage, and thermal shrinkage, have been the subject of numerous numerical or experimental studies in recent years. The results of these research shown that environmental factors, aggregate type, cementitious materials, water/cement ratio, and chemical admixtures all have an impact on the shrinkage properties. The resistance of many types of concrete to shrinkage and the emergence of fractures has been shown to be improved by several cementitious substitutes, such as flyash [3-5]. Given all these influences on shrinking behaviour, a thorough review paper that compiles and analyses recent data in the literature is required. Therefore, the purpose of this work is to review and contrast earlier studies on the concrete shrinkage behaviours.

2. TYPES OF SHRINKAGE

Major types of shrinkages that can occur over the maturity process and life span are classified as autogenous, plastic, drying, carbonation and thermal.

3.1 Autogenous Shrinkage

Autogenous shrinkage, in general, can be defined as the portion of shrinkage that does not involve any volume change caused by material loss or ingress, temperature variation, application of an external force, or restraint. Because of this, it is also known as self-desiccation shrinking.

Autogenous shrinkage was defined as the macroscopic volume reduction of cementitious materials when cement hydrates after initial setting [6-7] by a technical committee on autogenous shrinkage at the Japan Concrete Institute (JCI). According to ACI 116R, "change in volume induced by continuous cement hydration, excluding the effects of applied load and change in either heat condition or moisture content" [8] is what is meant by autogenous shrinkage.

3.2 Plastic Shrinkage

This type describes shrinkage that takes place while the concrete is still plastic state and the bonds between its components are weak. It occurs when the rate of water loss from the mixture exceeds the rate of surface bleeding prior to final setting. A complex menisci process shapes the liquid between the particles at and near the surface of concrete as it dries. Capillary action also results in the creation of a tensile capillary pressure within the liquid phase, which over time leads to the development of plastic shrinkage as the pressure rises. The primary factors that regulate plastic shrinkage cracking are the amount of cementitious elements employed in a concrete mix, the w/c ratio, and the environment. being incorporated

3.3 Drying Shrinkage

On cementitious composites, carbonation shrinkage is recognised to have less severe effects than carbonation itself. The microstructure of the concrete is reorganised, the volume of the concrete is decreased, counterintuitive porosity declines, and the differential shrinkage between the surface and the bulk of the concrete changes. In addition to drying and natural shrinkage, the carbonation reactions also cause volume reductions in the concrete. Due to the development of surface cracks, these modifications can minimise the start time prior to the corrosion of the steel reinforcement. This effect is especially severe for highly porous cementitious materials.

3.4 Carbonation Shrinkage

The carbonation shrinkage is known to have the lesser severe consequences of carbonation on cementitious composites. It reorganizes the concrete microstructure, reduces concrete volume, declines paradoxical in the porosity, and varies differential shrinkage between the surface and the bulk of concrete. Besides, drying and autogenous shrinkage, the concrete is also subjected to volume reductions due to the carbonation reactions. These changes can increase the carbonation level, due to the formation of surface cracks, and thus reduce the initiation time preceding the corrosion of the steel reinforcement and is more severe for highly porous cementitious materials.

3.5 Thermal Shrinkage

Because of the strains brought on by the heat produced during the hydration process and the temperature differences between the concrete and its surroundings, thermal shrinkage is the swelling and contraction of concrete. Thermal expansion is another name for the heating process that occurs in the first 12 hours after casting concrete. In general, a thermal strain is created when a concrete cross-section has an even temperature with a gradient as it begins to cool and reaches thermal equilibrium between its layers. Depending on the elasticity of heat expansion and the size of the concrete piece, this strain may cause cracks to spread. Thermal shrinkage will eventually form as a result of temperature fluctuations between the concrete's surface and the surrounding air, which could differ dramatically between the concrete section's inner and outer surfaces. Control joints are frequently utilised to reduce the thermal cracking caused by volume changes and thermal expansions. Multiple factors, including the w/c ratio, aggregate type, daily temperature variations during construction, location of the project, size of the structural components, and level of construction quality, all have an impact on thermal stress. Additionally, the thermal stress is somewhat influenced by the formworks being used [10].

4.INFLUENCE OF SUPPLEMENTARY CEMENTITIOUS MATERIALS ON SHRINKAGE OF CONCRETE

Ternary cementitious materials are frequently utilised in construction as a partial replacement for cement. These materials include ground granulated blast furnace slag and pozzolanic materials. Additionally, it is well recognised that these materials improve the mechanical and long-term performance of concrete. However, compared to regular concrete, alkali-activated slag concrete shrank more overall. The autogenous shrinkage of granulated blast furnace slag concrete increases with growing replacement level of blast furnace slag at the same w/c compared to plain concrete because of the high chemical shrinkage, fine pore structure, and particle shape of blast furnace slag. Alkali-activated slag concrete's shrinkage can be slightly decreased with shrinkage reducing chemicals under the right curing circumstances. Additionally, it was discovered that using blast furnace slag coarse aggregate in place of regular coarse aggregate in alkali-activated slag concrete significantly reduced drying shrinkage. Furthermore, the drying shrinkage was increased by the replacement of slag by up to 15%. However, the shrinkage was reduced when a higher percentage was used [11].

In contrast, shrinkage for concrete containing 60% slag was reduced by 19% at one year and by 35% at 30 days after curing when measured as a percentage of the volume of cement used in the mix. In comparison to ordinary cement mixes that contain coarse aggregate with low absorption, using slag cement with porous limestone coarse aggregate and water internally cured demonstrated a more noticeable decrease in free shrinkage. The strain on concrete's plastic and drying shrinkage increased when silica fume was added. Additionally, compared to normal concrete, silica fume cement concrete demonstrated a 69 percent increase in plastic shrinkage.

According to a study on short-term shrinkage, silica fume cement concrete experiences more of it than regular concrete, however both types of concrete exhibit somewhat equivalent long-term shrinkage. The study found that, under conditions of seven days of curing and 65 percent relative humidity, cement with a w/c ratio of 0.26 to 0.35 and a silica fume content of 0 to 10 percent showed increased overall shrinkage due to greater autogenous shrinkage but no difference in drying shrinkage. In conventional concrete with no silica fume, decreasing the w/c ratio from 0.35 to 0.30 led to a substantial increase in autogenous shrinkage from 40 to 180 micro stresses at 98 days. While the autogenous shrinkage up to 98 days was quite significant even at a w/c ratio of 0.35 (>200 micro strains) in the case of concrete with silica fume up to 10% by the weight of cement [12].

The introduction of additional materials, such as fly ash, has a favorable effect on the behaviour of concrete shrinkage; as fly ash content rises, drying shrinkage declines. More than 10% of fly ash replacement will significantly lessen shrinking. The amount of free drying shrinkage was reduced when fly ash was used, with a replacement rate of no more than 50%. When wet curing time is shortened, fly ash in concrete has a greater impact on drying shrinkage than ground granulated blast furnace slag or regular concrete. By adding 20% fly ash and slag to concrete, you can improve its workability and decrease the plastic shrinkage area. In comparison to the fly ash cement combination, micro silica and slag cement showed less drying shrinkage. In terms of autogenous shrinkage, fly ash and iron ore tailing powder in concrete exhibited similar behaviour. At the same water/binder ratio, the autogenous shrinkage decreased proportionately as the replacement increased. Other cement replacement fine materials, like employing limestone powder in concrete, demonstrated less drying shrinkage than ordinary cement concrete, or at least on par with it. In comparison to typical cement concrete, concrete containing 10% limestone powder shrunk somewhat less when it dried, but drying shrinkage in concrete containing 20% and 30% limestone powder was lower. This outcome is brought about by the fact that drying shrinkage decreases as the water/binder ratio decreases and that less hydration products are produced when more cement is replaced by limestone powder. Limestone powder is added to concrete to reduce autogenous shrinkage. When fine limestone was used in place of cement paste, the amount of eventual shrinkage was reduced by nearly 28 percent. Additionally, at 5 years, the drying shrinkage of concrete containing 10% limestone powder is marginally less than that of concrete made only of cement, whereas concrete containing 20% and 30% limestone powder showed less drying shrinkage.

The effects of employing river sand rather than dune sand on the drying shrinkage of concrete were demonstrated in the investigation. They discovered that concrete made with a blend of 60% river sand and 40% dune sand performs noticeably better than concrete made entirely with dune sand. Concrete drying shrinkage is significantly reduced when metakaolin is used in place of cement to the extent of 5 to 20 percent. However, the effect of metakaolin was reversed and shrinkage accelerated above a 20 percent replacement level. In addition, employing 100 percent glass cullet sand in concrete reduced shrinkage by 16 percent, which can be attributed to the material's almost negligible porosity and low water absorption rates, which prevent moisture from moving from the concrete to its surroundings[13].

8. CONCLUSION

This review paper highlights the results of research investigations on various types of concrete and the variables affecting the concrete's shrinkage qualities that have been published over the years. In general, various investigations shown that concrete shrinkage begins at a young age. Depending on the shrinkage characteristics of concrete, which are influenced by a variety of elements such as humidity, w/c ratio, type of coarse aggregate, shape, and hardness of aggregates, usage of supplemental cementitious materials, and curing conditions, it goes through many stages over time. Water loss in the paste has a direct impact on shrinkage cracking, which can be prevented by limiting the amount of paste used, controlling the w/c ratio (0.4–0.5), using the right curing methods, and adding chemical admixtures. While plastic shrinkage and autogenous shrinkage are the main issues for greater strength concrete when w/c is near 0.3.The addition of supplementary cementing ingredients such fly ash, slag, and limestone powder has a significant impact on the shrinkage properties of concrete. In general, silica fume-infused concrete was shown to have more short-term shrinkage. On the other hand, the more regular cement is substituted with limestone powder, the better the results are at resisting long-term shrinkage.

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