Experimental investigation on autogenous shrinkage of high and ultra-high strength concrete

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Abstract. Recent trends in concrete technology have been towards high-strength concrete and ultra-high-strength concrete with a low water-cement ratio. However, these high and ultra-high strength concretes have some problems. One of the problems is early-age cracking due to autogenous shrinkage. This study presents the results of an experimental investigation carried out to evaluate the autogenous shrinkage of high and ultra-high strength concrete. Main ideas on autogenous shrinkage are based on the use of ordinary Portland cement, but it has already become apparent that mineral admixtures and fibers change the behavior significantly. Variables were taken to study its effect on shrinkage like (effects of water/cement ratio, cement content, coarse aggregate content, silica fume percentage and steel fiber). From the test results, it is concluded that the autogenous shrinkage strain of mixes increases with decrease w/c ratio and decrease with increasing w/c ratio and concrete with the higher value of cement content, shows greater amounts of shrinkage. The autogenous shrinkage strain increases with decreasing of the coarse aggregate content. The additions of 10-20 % of silica fume to the mix increase the autogenous shrinkage strains of concrete specimens. The autogenous shrinkage decreased gradually with the increase of steel fiber content.

Keywords: High, Ultra High-Strength Concrete, Autogenous Shrinkage, Silica Fume, Strain and Steel Fiber.

1. Introduction
High-strength concrete and ultra-high-strength concrete are extensively employed throughout the world and their productions are essential to decrease water/binder ratio and increase binder content. It manages to demonstrate preferred properties such as the strength of high-level, durability, and stability for long-term. Usually, various types of cementitious materials additives are typically added to concrete because porosity is low and permeability is acceptable, but these additives head to the increased shrinkage. Researchers and engineers have focused on strengthening concrete properties, especially their strength and usability operation (workability) and resistance to cracking. Concrete subject to volume change is known as concrete shrinkage or concrete swelling. The concrete shrinkage leads to cracking which weakens the serviceability, strength, and durability of materials. There are many kinds of shrinkage that affecting the concrete, are existed namely drying shrinking, autogenous shrinking, chemical shrinking, carbonation shrinking, heat shrinking and plastic shrinkage [1]. Due to the high content of cementitious materials, low water-to-cementitious materials (w/cm) ratio, the ratio of water to binder (w/b) materials and various additives in concrete, all these factors straight directed to shrinkage cracking. Shrinking is a degraded concrete size (volume) over time [2]. This decrease is due to changes in the moisture content of concrete and physical and chemical changes, which happen without stress due to the external action of the concrete. When does not allow transfer of moisture with the environment, this change in volume is called autogenous shrinkage and causes because of self-dehydration because of concrete moisturization. Not appear regularly in conventional concrete (normal
strength concrete) but develops in high and ultra-strength concrete [3]. Autogenous shrinkage is recognized as a volume change when the concrete has no moisture transport to the surrounding environment, it happens at different stages, even during the very early stage while the concrete is still liquid. As the cement hydrates, more water is consumed and concrete starts to harden. During this stage (hardening phase), the water miniscay develops within the fine pores, and it generates pressure (stress) on the porous walls, causing the concrete to shrink. As concrete reaches the hardening phase, self-drying results, and leading to shrinkage [4]. Autogenous shrinkage cannot be controlled by the practice of construction, but the design of the mixture can have a significant effect on it. “Autogenous shrinkage” correlated closely to the chemical shrinkage throughout the very early hours, so the chemistry of cement and fineness has a significant impact on shrinkage. The delay in the stiffening and the development of the concrete strength leads to prolongation of the period of early age autogenous shrinkage and can be affected by the parameters of the mixture. Shrinking is occurring with the higher percentage when adding superplasticizer, due to better cement dispersion, and may be higher if the preparation and setting time is delayed (delayed time setting), which can be for example caused due to added chemicals or temperature [5]. Silica fume is one of the most popular pozzolans, which in addition to the concrete mixture leads to less porosity, permeability, and bleeding [6].

1.1. Previous Studies

Autogenous shrinkage strain of HSC and UHSC is considerably much larger than the standard concrete strain. This may not only be attributed to the high paste volume but however, it’s the combined impact of the paste volume and the decrease w/p. A reduction in paste volume by adding fine granular aggregates will fundamentally reduce autogenous shrinkage. Further increase within the amount of mineral admixtures additives is found to augment both (autogenous and drying shrinkage) as a result of the specific gravity of those minerals is less than that of ordinary Portland cement. It's additionally realized that the ratio of water/cement has a significant impact and affects the shrinkage. Concrete mixtures containing additional water mean less hardness and additional more pores, that successively, will result in higher drying shrinkage and lower autogenous shrinkage. Numerous researchers reported and revealed that HSC and UHSC may be cracked due to autogenous shrinkage distortions. Adding steel fibers may lead to a reduction in shrinkage [7]. [8] study and examine the autogenous shrinkage of HSC with the impacts of water/binder ratio and silica fume. They presumed that high stress caused by the restrained autogenous shrinkage and these leads to cracking of concrete. [9] displayed the mechanisms of early age’s shrinkage and ultrasonic propagation estimations for UHPC based materials. [10] exhibited a test investigation of the curing temperature effect and type of cement on autogenous shrinkage of superior HPC. They reasoned that to the higher temperature and results to increase shrinkage and stresses. [11] they study the HSLWA lightweight aggregate concrete in term of limited restrained autogenous shrinkage. The results demonstrate that autogenous shrinkage and restrained stresses can be eliminated by lightweight aggregate as a substitution of normal-weight aggregate. [6] displayed the utilization of silica fume of (0, 6, 10 and 15 %,) and its impacts on HSC properties. The results demonstrate that increasing of silica fume results in a reduction of workability of concrete, with an increase in compressive strength and modulus of elasticity, and increasing in the autogenous shrinkage of concrete. [12] study the properties of the cement paste matrix on the autogenous of HPC, [13] examine the behavior of thermo-mechanical at early-age for large prismatic specimens of HPC concrete under restrained autogenous shrinkage and realistic temperature conditions. [14] introduced an experimental trial study and then derived a formula for long-term creep and shrinkage of HSC estimations with silica fume ratios of (0, 6, 8, 10 and 15%) with w/b ratio proportions of 0.35. [15] study of the HSC concrete shrinkage with cement partial substitution by fly ash and silica fume. They found that concrete with 10% of Flyash and Silica fume expanded the shrinkage from (6 to 10%). [16] presented an experimental examination on the impact of mineral admixture shrinkage and cracking with the utilization of fly ash and limestone powder. They inferred those additive materials significantly increase the cracking age of concrete. [17] exhibited the expansive and shrinkage reducing agent solutions to the concrete mixture to diminish the shrinkage of UHPCC. The results demonstrate that shrinkage was reduced by (30 to 50%). [18] study the addition of shrinkage-reducing admixtures and superabsorbent polymers on the properties of UHPCC concrete.
In this examination, the autogenous shrinkage strain and compressive strength behavior in HSC and UHSC were researched with the impacts of water/cement ratio, cement content, coarse aggregate content, silica fume percentage and steel fiber.

2. Experimental work

2.1. Materials and Methods

The following materials were employed in the current research and they are included:

2.1.1. Cement, fine aggregate and coarse aggregate. Type I, Ordinary Portland cement that meets the states of [ASTM C150-89]. The natural regular sand with (4.75 millimeters) extreme size. They were clean, without organic matter and mud. The results enlisted that the aggregate grading and the sulfate content were inside the arrangements of Iraqi specifications. Coarse aggregate utilized during this work with the most size of ten millimeters. The grading evaluating of coarse aggregates is followed the Iraqi specifications [No.45 / 1984].

2.1.2 Mineral Admixture Silica Fume (SF) and superplasticizer. Gray silica fume from (Basif Materials Company) was adopted as a mineral mixture added to the mixtures, conformist to the chemical and physical specifications of [ASTM C1240-04]. It's an exceptionally active pozzolanic substance and extremely fine powder, with particles lower than one hundred times the common grain of cement. The fundamental benefits of superplasticizers incorporate high-strength concrete with typical workability but however low water content. The superplasticizer adopted was a modified polycarboxylate compound polymer made and provided by SIKA® within the exchange name (Sika ViscoCrete 5930). It has three faculties, specifically the superplasticizer, the viscosity modifying agent, and the retarder, which upgrades the compressive, tensile and flexural strength due to the water diminishment characteristics as determined in [ASTM C109/C109M-05] and [ASTM C1240-03].

2.1.3 Steel Fibers. Steel fibers with high tensile compose as indicated by the prerequisites of [ASTM A820/A 820M-04] for kind II (Cut Sheet Fibers) was utilized with (L=13 millimeter and D=0.2 millimeter round with aspect ratio of 65 and tensile strength of 2600MPa). It's factory-made by the corporate (Hebei Yusen Metal Wire Mesh, China).

2.2. Mix Proportions

Two concrete types (HSC high and UHSC ultra-high strength concrete) were utilized to study the shrinkage under various factors. Variables like (effects of water/cement ratio, cement content, coarse aggregate content, silica fume percentage and steel fiber content) as shown in tables 1 and 2 with the proportion of the constituents for the prepared concrete mixes as demonstrated as follows:

1- For high strength concrete HSC (1: 1.8: 1.7) (by weight of ordinary Portland cement: fine aggregate: coarse aggregate with w/c ratio of 0.35).
2- For ultra-high strength concrete UHSC (1: 1: 0) (by weight of ordinary Portland cement: fine aggregate: coarse aggregate with w/c ratio of 0.2).

| Mix | Cement (kg/m³) | Sand (kg/m³) | Aggregate (kg/m³) | Steel Fiber (%) | Silica Fume (%) by weight of cement | w/c | Superplasticizer (%) by weight of cement | Variables |
|-----|---------------|--------------|-------------------|----------------|-----------------------------------|-----|----------------------------------------|-----------|
| 1   | 500           | 900          | 850               | 0              | 0                                 | 0.35| 2.0                                    | Silica fume|
| 2   | 450           | 900          | 850               | 0              | 0                                 | 0.35| 2.0                                    | w/c       |
| 3   | 400           | 900          | 850               | 0              | 20                                | 0.35| 2.0                                    | Cement content|
| 4   | 450           | 900          | 850               | 0              | 10                                | 0.35| 2.0                                    | Aggregate content|
| 5   | 450           | 900          | 850               | 0              | 10                                | 0.35| 2.0                                    | w/c       |
| 6   | 450           | 900          | 850               | 0              | 10                                | 0.35| 2.0                                    | Aggregate content|

Table 1. Mix design for high strength concrete.
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**Table 2. Mix design for ultra-high strength concrete.**

| Mix | Cement (kg/m³) | Sand (kg/m³) | Aggregate (kg/m³) | Steel Fiber (%) | Silica Fume (% by weight of cement) | w/c | Superplasticizer (% by weight of cement) | Variables |
|-----|----------------|--------------|-------------------|-----------------|-------------------------------------|-----|------------------------------------------|-----------|
| 1   | 900            | 900          | ---               | 0               | 25                                  | 0.2 | 6.25                                     | Steel fiber content |
| 2   | 900            | 900          | ---               | 0.5             | 25                                  | 0.2 | 6.25                                     | Steel fiber content |
| 3   | 900            | 900          | ---               | 1               | 25                                  | 0.2 | 6.25                                     | Steel fiber content |
| 4   | 900            | 900          | ---               | 1.5             | 25                                  | 0.2 | 6.25                                     | Steel fiber content |
| 5   | 900            | 900          | ---               | 2               | 25                                  | 0.2 | 6.25                                     | Steel fiber content |
| 6   | 900            | 900          | ---               | 0               | 20                                  | 0.2 | 6.25                                     | Steel fiber content |
| 7   | 900            | 900          | ---               | 0               | 30                                  | 0.2 | 6.25                                     | Steel fiber content |
| 8   | 900            | 900          | ---               | 2               | 20                                  | 0.2 | 6.25                                     | Steel fiber content |
| 9   | 900            | 900          | ---               | 2               | 30                                  | 0.2 | 6.25                                     | Steel fiber content |
| 10  | 900            | 900          | ---               | 0               | 25                                  | 0.25| 6.25                                     | w/c        |
| 11  | 900            | 900          | ---               | 0               | 25                                  | 0.3 | 6.25                                     | w/c        |

**2.3. Preparation of Samples, Mixing Procedures, Casting, Compaction and Curing**

All concrete is blended and placed within the similar method. The dry materials (cement and silica) were mixed at first, and this procedure keeps on ensuring that the silica fume was fully scattered among the cement particles. At that point, the fine sand was stacked into the mixer. The materials were mixed until a standardized color was achieved. For high strength concrete aggregated were supplemented and mixing has proceeded until the point when the dry blend ended up homogenous. At last, for the two sort mixes, the water, and the superplasticizer were step by step included while the mixer was in movement and mixing proceeded until the point when a uniform blend was accomplished. For mixtures containing steel fibers, utilize a similar strategy procedure and include the steel fibers after including the water with the superplasticizer, at that point keep mixing until the point that the concrete is homogeneous in consistency. As indicated by [ASTM C192 / C192M-02], for the compressive strength test, cylinders and cubes loaded with composite material carefully and cast into form in two layers. After smoothing the surface with a steel scoop, the samples were secured with plastic sheets to anticipate moisture loss and after that stored at the laboratory, temperature preceding to demolding. Following one day of pouring the samples were demolded and marked and set in water for treatment until testing. As for the shrinkage, the samples were casting and kept similarly as the compression strength, and then the samples kept in the mold until the second day. At that point, one side of the mold was opened and the strain measuring instruments were attached to the mold and started to read the deformations of the autogenous shrinkage strain.

**2.4. Compressive strength test**

Cubes and cylinders of (100x100x100 millimeter cube) and (100x200 millimeter cylinder) were identified to assess the compressive strength at the age of 28 days for each mixture. The compressive strength investigation managed according to [ASTM C39-2005] and [B.S-1881; Part 116] utilizing the Universal Digital Hydraulic testing machine (ELE-Digital Elect 2000) of capability 2000 kN. The load rate for all tests was rated at (15MPa per minute), as per [ASTMC109/C109M-05]. The average compressive strength was enrolled for three samples.

**2.5. Autogenous Shrinkage test**

A One-dimensional autogenous shrinkage was evaluated on fixed sealed samples. The cross-sectional area of the specimen was (100*100*400 millimeter height*width*length). External surface drying was hindered by sealing samples immediately after casting employing two layers of polystyrene sheets. Extraordinary preparation is required to guarantee that strains on the concrete surface are effectively transmitted. The data logger (TML/C-530) was utilized to measure the strain, as appeared in Figure 1. When pouring the prism directly wrapped in plastic foil and sealed with aluminum foil to prevent moisture transfer with encircling environment. The prisms then placed in a climatic chamber, where the temperature is (20°C±2). After one day of casting, one side of the mold is removed and the test is
conducted by connecting a measuring device (LVDT) (linear variable displacement transducer), autogenous deformation data is recorded on one side of the prism and the measurements are taken in (0, 3, 7 and 14 and 28 days) at the same time. The information data is taken by the data logger and stored. Figure 2 indicates autogenous-shrinkage test preparation and estimation.

**Figure 1.** Data logger used and Setup for the measurement of autogenous-shrinkage.

**Figure 2.** Autogenous-shrinkage preparation test and measurement.

### 3. Results and Discussions

3.1. For High Strength Concrete (HSC)

3.1.1. Effects of water/cement ratio on compressive strength and Autogenous shrinkage. Four w/c ratios were examined to review its consequences on compressive strength and autogenous shrinkage. From the test outcomes, it is presumed that the autogenous shrinkage strain of mixes increases with decrease the w/c ratio and decrease with increasing w/c ratio. Hydration of the cement, require the water in the cement paste. These results demonstrate that high and ultra-high strength concrete containing higher cement content indicates large autogenous shrinkage strain because increases the paste volume. The water existence in concrete is required to proceed with the hydration of cement. Whenever w/c decreases from (0.35 to 0.3) an increase in compressive strength of about (8.57%) and (21.21%) in autogenous shrinkage were accomplished. When w/c increase from (0.35 to 0.4 and 0.45) a decrease in compressive strength of about (5.71and 17.14%) (24.24 and 36.36%) in autogenous shrinkage were achieved, as appeared in figures 3 and 4 and table 3.

| Mix | w/c     | $f_c$ (MPa) | Compressive strength (%) | 3d  | 7d  | 14d | 28d  |
|-----|---------|-------------|--------------------------|-----|-----|-----|------|
| 2   | 0.35    | 70          |                          | 60  | 145 | 165 | 165  |
| 4   | 0.3     | 76          | 8.57                     | 70  | 170 | 190 | 200  |
| 5   | 0.4     | 66          | -5.71                    | 60  | 95  | 125 | 125  |
| 6   | 0.45    | 58          | -17.14                   | 42  | 80  | 105 | 105  |

Table 3. Effect w/c ratio on compressive strength and autogenous shrinkage of HSC.
3.1.2. Effects of cement content on compressive strength and Autogenous shrinkage

Three cement contents were considered to review its impacts on compressive strength and autogenous shrinkage. High-strength concrete containing higher cement content shows higher autogenous shrinkage strain owing to the higher estimation of hydrated cement paste. At the point when cement content decreases from (450 to 315) a reduction in compressive strength of around (17.14%) and (12.12%) in autogenous shrinkage was accomplished. At the point when cement content increases from (450 to 540) an increase in compressive strength of around (2.86%) and (15.15%) in autogenous shrinkage were accomplished, as appeared in figures 5 and 6 and table 4.

Table 4. Effect cement content on compressive strength and autogenous shrinkage of HSC.

| Mix | Cement content (kg/m³) | f’c (MPa) | Compressive strength (%) | Strain (µ) | 28d Strain (%) |
|-----|------------------------|-----------|--------------------------|------------|----------------|
| 2   | 450                    | 70        | 0                        | 60         | 145 165 165   |
| 7   | 315                    | 58        | -17.14                   | 60         | 125 145 145   |
| 8   | 540                    | 72        | 2.86                     | 70         | 165 190 190   |

3.1.3. Effects of coarse aggregate on compressive strength and Autogenous shrinkage

Three aggregate contents were chosen to study its consequences on compressive strength and autogenous shrinkage. The autogenous shrinkage strain increases with decreasing of coarse aggregate content and this is related that the concrete will be more homogeneous. When aggregate content decreases from (850 to 750) an increase in compressive strength of about (4.29%) and (27.27%) in autogenous shrinkage were achieved. At the point when aggregate content increase from (850 to 1100) a decrease in compressive strength of about (25.71%) and (15.15%) in autogenous shrinkage was achieved, as appeared in figures 7 and 8 and table 5.

Table 5. Effect aggregate content on compressive strength and autogenous shrinkage of HSC.

| Mix | Aggregate content (kg/m³) | f’c (MPa) | Compressive strength (%) | Strain (µ) | 28d Strain (%) |
|-----|---------------------------|-----------|--------------------------|------------|----------------|
| 2   | 850                       | 70        | 0                        | 60         | 145 165 165   |
| 9   | 750                       | 73        | 4.29                     | 70         | 150 190 210   |
| 10  | 1100                      | 52        | -25.71                   | 60         | 125 145 140   |

3.1.4. Effects of silica fume on compressive strength and Autogenous shrinkage

Three silica fume proportions were examined for its consequences on compressive strength and autogenous shrinkage. The addition of silica fumes to the mix increases the autogenous shrinkage strains of high-strength concrete with time. The augmentations of (10-20%) of silica fume to the mix increase the autogenous shrinkage strains of concrete specimens. This might be because of the expansion pastes that cause large shrinkage by partially replacing cement with silica fume that have a higher specific surface area. When silica fume decreases from (10 to 0%) a decrease in compressive strength of about (10%) and (12.12%) in autogenous shrinkage were achieved. When silica fume increase from (10 to 20%) an increase in compressive strength of about (7.14%) and (18.18%) in autogenous shrinkage was accomplished, as appeared in figures 9 and 10 and table 6.

Table 6. Effect silica fume on compressive strength and autogenous shrinkage of HSC.

| Mix | Silica fume % | f’c (MPa) | Compressive strength (%) | Strain (µ) | 28d Strain (%) |
|-----|---------------|-----------|--------------------------|------------|----------------|
| 2   | 10            | 70        | 0                        | 60         | 145 165 165   |
| 1   | 0             | 63        | -10.00                   | 60         | 105 125 145   |
| 3   | 20            | 75        | 7.14                     | 70         | 175 190 195   |

3.1.5. Effects of steel fiber content on compressive strength and Autogenous shrinkage

Five steel fiber ratios proportions were considered its impacts on compressive strength and autogenous shrinkage. The autogenous shrinkage diminished step by step with the expansion of steel fiber content. The reason of autogenous shrinkage diminished was that the dispersion of steel fiber demonstrated a three-dimensional irregular state, the structure was formed by the lap joint between steel fiber, and coupled with the high elastic modulus of steel fiber itself, the inner stress (internal pressure) which
created from hardening matrix shrinkage was incompletely compensated. Consequently, the autogenous shrinkage of the specimens with steel fiber was lower than the mix without steel fiber. At the point when steel fiber increase form (0, 0.5, 1.0, 1.5 and 2.0%) an increase in compressive strength of (0, 8.57, 14.29, 15.71 and 18.57%) and diminishing in autogenous shrinkage of (0, 9.09, 21.21, 27.27 and 29.69%), has appeared in figures 11 and 12 and table 7.

Table 7. Effect steel fiber on compressive strength and autogenous shrinkage of HSC.

| Mix | Steel fiber % | f'c (MPa) | Compressive strength (%) | Strain (µ) | Strain (%) |
|-----|---------------|-----------|--------------------------|------------|------------|
|     |               | 28d Strain | 3d 14d 28d Strain       | 3d 7d 14d 28d Strain | 3d 7d 14d 28d Strain |
| 2   | 0             | 70        | 0                         | 60 145 165 165 | 0.00       |
| 11  | 0.5           | 76        | 8.57                      | 55 120 140 150 | -9.09      |
| 12  | 1             | 80        | 14.29                     | 55 100 120 130 | -21.21     |
| 13  | 1.5           | 81        | 15.71                     | 50 87 104 120 | -27.27     |
| 14  | 2             | 83        | 18.57                     | 48 84 100 116 | -29.69     |

Figure 3. Effect of w/c ratio on compressive strength of HSC.

Figure 4. Effect of w/c ratio on autogenous shrinkage of HSC.

Figure 5. Effect of cement content on compressive strength of HSC.

Figure 6. Effect of cement content ratio on autogenous shrinkage of HSC.

Figure 7. Effect of aggregate content on compressive strength of HSC.

Figure 8. Effect of aggregate content ratio on autogenous shrinkage of HSC.
3.2. For Ultra-High Strength Concrete (UHSC)

3.2.1. Effects of water/cement ratio on compressive strength and Autogenous shrinkage. Three w/c proportions were examined for its consequences on compressive strength and autogenous shrinkage. Ultra High-strength concrete with higher w/c demonstrates lower autogenous shrinkage strain in light of the higher estimation of hydrated cement paste. The water existence in concrete is required to proceed with the hydration of cement. When w/c increases from (0.2 to 0.25 and 0.3) a decrease in compressive strength of around (7.32 and 14.63%) and (15.35 and 32.09%) in autogenous shrinkage were accomplished, as appeared in figures 13 and 14 and table 8.

| Mix | w/c  | \( f'_c \) (MPa) | Compressive strength (%) | Strain (µ) | Strain (%) |
|-----|------|------------------|--------------------------|------------|------------|
| 1   | 0.2  | 82               | 0                        | 210        | 368        | 438        | 508        | 0.00        |
| 10  | 0.25 | 76               | -7.32                    | 157        | 276        | 360        | 430        | -15.35      |
| 11  | 0.3  | 70               | -14.63                   | 143        | 250        | 298        | 345        | -32.09      |

3.2.2. Effects of steel fiber content on compressive strength and Autogenous shrinkage. Five steel fiber proportions were contemplated by its impacts on compressive strength and autogenous shrinkage. The autogenous shrinkage of the specimens with steel fiber was lower than the mix without steel fiber. At the point when steel fiber increase form (0, 0.5, 1.0, 1.5 and 2.0%) an increase in compressive strength of around (0, 15.85, 28.05, 39.02 and 46.34%) and (0, 13.98, 25.0, 35.04 and 45.07%) in autogenous shrinkage were accomplished, as appeared in figures 15 and 16 and table 9.

| Mix | Steel fiber % | \( f'_c \) (MPa) | Compressive strength (%) | Strain (µ) | Strain (%) |
|-----|---------------|------------------|--------------------------|------------|------------|
| 1   | 0             | 82               | 0                        | 210        | 368        | 438        | 508        | 0.00        |
| 2   | 0.5           | 95               | 15.85                    | 181        | 316        | 377        | 437        | -13.98      |
| 3   | 1             | 105              | 28.05                    | 158        | 276        | 329        | 381        | -25.00      |
| 4   | 1.5           | 114              | 39.02                    | 137        | 239        | 285        | 330        | -35.04      |
3.2.3. Effects of silica fume on compressive strength and Autogenous shrinkage. Three silica fume proportions were considered its impacts on compressive strength and autogenous shrinkage. The addition of silica fumes to the mix increases the autogenous shrinkage strains of high-strength concrete with time. This might be because of the expansion pastes that cause large shrinkage as a result of silica fume that have a higher specific surface area. Without steel fiber (0%) when silica fume decreases from (25 to 20%) a reduction in compressive strength of around (4.88%) and (10.04%) in autogenous shrinkage was accomplished. At the point when silica fume increase from (25 to 30%) an increase in compressive strength of around (9.76%) and (18.11%) in autogenous shrinkage was accomplished. With steel fiber of (2%), when silica fume decreases from (25 to 20%) a decrease in compressive strength of (4.17%) and (7.89%) in autogenous shrinkage was accomplished. When silica fume increase from (25 to 30%) an expansion in compressive strength of (5.0%) and (11.83%) in autogenous shrinkage, as appeared in figures. 17, 18, 19 20 and 21 and table 10.

Table 10. Effect silica fume on compressive strength and autogenous shrinkage of UHSC.

| Mix | Silica fume % | Steel fiber % | $f'_c$ (MPa) | Compressive strength (%) | 3d Strain (µ) | 7d Strain (µ) | 14d Strain (µ) | 28d Strain (µ) |
|-----|---------------|---------------|--------------|--------------------------|---------------|---------------|----------------|---------------|
| 1   | 25            | 0             | 82           | 0                        | 210           | 368           | 438            | 508           |
| 6   | 20            | 0             | 78           | -4.88                    | 189           | 331           | 394            | 457           |
| 7   | 30            | 0             | 90           | 9.76                     | 248           | 434           | 517            | 600           |
| 5   | 25            | 2             | 120          | 0                        | 116           | 202           | 241            | 279           |
| 8   | 20            | 2             | 115          | -4.17                    | 107           | 186           | 222            | 257           |
| 9   | 30            | 2             | 126          | 5.00                     | 130           | 226           | 270            | 312           |
4. Conclusions
The resulting conclusions were achieved from this examination on autogenous shrinkage of high (HS) strength concrete and ultra-high (UHSC) strength concrete:

1. The employment of high strength and ultra-high strength concrete experience and faces a problem like, the early-age cracking due to autogenous shrinkage.
2. The present investigation studies the autogenous shrinkage of high and ultra-high strength concrete with multiple variables and factors including like, (effects of w/c ratio, cement content, coarse aggregate content, silica fume percentage and steel fiber content).
3. Two concrete type’s mixes with different proportions were used in this research with high and ultra-high strength concrete properties to study its effect on shrinkage.
4. For high (HS) strength concrete and ultra-high (UHSC) strength concrete results showed that higher percentages of cement content show large autogenous shrinkage strain and compressive strength because it is related to paste volume. Decreasing of w/c caused an increase in compressive strength and autogenous shrinkage.
5. For high (HS) strength concrete and ultra-high (UHSC) strength concrete the autogenous shrinkage strain and compressive strength increase with decreasing of coarse aggregate content because that the mixture will be nearly of the same particle size leading to the concrete turn to be homogeneous.
6. Silica fumes addition with (10-20%) to the concrete mix increases the autogenous shrinkage strains and compressive strength for HSC and UHSC concrete because of formation of pastes related to the higher specific surface area of silica fume.
7. Autogenous shrinkage for HSC and UHSC with steel fiber was lower than the mix without steel fiber and decreased gradually with the increase of steel fiber and compressive strength increase and this is related to the distribution of steel fiber in the mix causing inner stress which generated from hardening so that shrinkage was partly compensated.
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