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Developing of High-Strength Concrete with Locally-Sourced Materials

Hesham A. Amna[1] , Amr H. Zaher[2], Tarek El Hashimy[3]

1- Demonstrator, Construction and Building Department, October 6 University, Giza, Egypt.
2- Professor, Structural Engineering Department, Ain Shams University, Cairo, Egypt.
3- Assistant Professor, Structural Engineering Department, Ain Shams University, Cairo, Egypt.

الملخص:يحتوى هذا البحث على دراسة معملية لعدة خلطات خرسانية عالية المقاومة ، وقد تم انتاجها بواسطه مواد محلية الصنع ، تم استنتاج ثمانية خلطات خرسانية حيث كان اكبر اجهاد ضغط تم الحصول علية 135.6 ميجا باسكال، فتطور هذه الخلطات لا يقلل من تكاليف انتاج المنشات الخرسانية فقط بل ايضا يعزز استدامة المنشات. وقد شمل البحث ايضا خصائص المواد المستخدمة ، وتم استنتاج تأثير المعاجة باستخدام البخار وتأثيرها علي الخصائص الميكانيكية للخلطات الخرسانية وبناء علي النتائج المعملية ، يوصي بشده باستخدام هذه الخلطات الخرسانية في التصميمات الانشائية.

Abstract: This paper outlines the progress in creating high-strength concrete (HSC) by incorporating locally available materials. The development of HSC mixtures using indigenous resources aims to increase affordability for a wider range of applications. Specifically, the research utilized local sand with a maximum particle size of 600 μm and locally accessible type I cement and silica fume. These material selections are considered to contribute to the enhancement of HSC's sustainability. Eight mixtures were recommended as the HSC mixtures. The greatest compressive strengths obtained in this study were 135.6 MPa for HSC with steel fibers and 98.5 MPa for HSC without fibers. The development of these novel mixes using local materials not only lowers material costs but also enhances sustainability .Tests were also carried out on the modulus of elasticity and modulus of rupture. The results highlight the significant impact of steam curing and the inclusion of steel fiber in the mixture on both compressive and tensile strength. Based on the practical results, these formulations are highly recommended for reinforced concrete applications if combined with a suitable mix design.

Keywords: Compressive strength, local materials, modulus of rupture, sustainability, high strength.

1. Introduction

In recent years, there have been notable advancements in concrete technology. The sustainable utilization of supplementary materials and super-plasticizer admixtures have an important role in enhancing the mechanical properties of concrete structures. Researchers have turned to silica fume and high-range water-reducing admixtures (HRWRA) to develop high strength concrete. Techniques like applying pre-setting pressure and post-setting heat treatments have been explored to achieve a compact microstructure[1]. Furthermore, methods such as utilizing numerical packing models to optimize particle mixture packing density have been employed to boost concrete density. These approaches have enabled the attainment of compressive strengths exceeding 200 MPa [2], [3]. In addition to achieving high strength, it is essential for concrete to demonstrate superior durability characteristics. This entails a concrete that possesses high strength and exceptional performance[1]. Recent material innovation is ultra high strength concrete (UHSC), which exceeds the strength of high-strength concrete and is also known as reactive powder concrete (RPC). UHSC exhibits compressive strengths surpassing 120 MPa and is typically composed of cement, fine quartz sand, silica fume, steel fibers, and high-range water-reducing admixtures (HRWRA). To create this type of concrete, very low water-to-cementitious materials (w/cm) ratios are utilized [4].

The capability of attaining high strength, durability, and enhanced ductility by using high-strength concrete (HSC) motivates researchers and engineers to consider this advanced material for various practical applications.

These applications include but are not limited to nuclear waste containment structures, high-rise buildings, long-span bridges, and pedestrian walkways. In this current study, efforts were directed toward formulating high-strength concrete (HSC) mixtures using materials readily available locally. The components utilized in this research comprised Type II Portland cement, silica fume, fine sand, and steel fibers. Various mixtures were devised, some including steel fibers and others without, to examine the impact of steel fibers on compressive strength. Additionally, factors such as curing procedures, which play a role in influencing compressive strength, were also scrutinized.

1.1Background

High-strength concrete (HSC) combines cement, fine sand, quartz powder, micro silica, steel fibers, and high-range water-reducing admixtures (HRWRA). Optimal dosages of HRWRA reduce the water-to-cementitious materials (w/cm) ratio while enhancing the workability of the concrete. The incorporation of microsilica enhances the mechanical properties of the paste by filling voids, improving rheology, and facilitating the formation of secondary hydrates. Quartz powder contributes reactivity during Steam treatment[5]. The mechanical characteristics of HSC are achieved through reducing the w/cm ratio, utilizing HRWRAs, and including silica fume. The lower w/cm ratio reduces the porosity of the cement paste and improves durability [5]. Several principles are recommended for developing concrete with higher strength. The removal of coarse aggregate is advised to improve the homogeneity of the concrete mixture. Additionally, adding silica fume is essential to initiate the pozzolanic reaction, which contributes to the overall strength and durability of the concrete. The optimization of the granular mixture is also crucial, as it enhances the compacted density of the concrete, leading to better strength. Furthermore, steam treatment improves the mechanical properties of the concrete's microstructure, ensuring a durable material. Lastly, adding steel fibers is recommended to impart ductility to the concrete, enhancing its performance and mechanical properties.

1.2 Sustainability

Materials like quartz powder and steel fiber, commonly used in High-Strength Concrete (HSC), are frequently transported over long distances, sometimes internationally, leading to increased material costs. Moreover, stringent specifications for the chemical composition of cement and silica fume raise the expenses of commercially accessible prepackaged HSC products. This study concentrated on formulating more sable mixtures using local materials to make it more cost-effective for a broader range of applications. Specifically, this research employed local sand with a maximum size of 600 μm and locally sourced Type II cement and silica fume. These material choices are viewed as sustainable enhancements for HSC. Furthermore, the utilization of higher-strength materials allows for the possibility of reduced sizes for structural elements, subsequently decreasing the concrete volume necessary to construct a specific structural component.

2. Experimental program

2.1 Materials

2.1.1 Cement

The cement used in this research was the Ordinary Portland Cement (OPC) of grade CEM I 52.5 N cement. Cement tests were carried out according to Egyptian Code No. 373/1991. This type of cement is suitable for all ordinary construction work. It does not resist sulfate attack and has a medium rate of strength. It has resistance to dry shrinkage and crushing but less resistance to chemical attack, thaw-freezing, and abrasion. **Table 1** shows the physical and chemical properties of the CEM I 52.5 N cement.

Table 1: Physical and chemical properties of Portland cement CEM I 52.5 N.

Specifics	Result	Standard Specification
Chemical composition		
SiO_2	20.4%	
Al_2O_3	4.72%	
Fe_2O_3	3.74%	
CaO	62.89%	
MgO	1.26%	Max 5.0
SO_3	2.57%	Max 4
K_2O	0.26%	
Na_2O	0.44%	
CL	0.051%	<0.10
Cr+6	1.84 ppm	<2 ppm
Insoluble residue	0.51%	Max 5.0
Loss on ignition	1.87%	Max 5.0
C_3S	53.8%	
C_2S	18.85%	
C_3A	6.19%	
C_4AF	11.36%	
Physical properties		
Fineness (Blaine)	3496 cm^2/g	
Expansion	0.50 mm	Max 10
Compressive strength		
2 Days	25.70 MPa	Min 10
28 Days	56.8 MPa	Min 42.5
Initial Setting Time	175 Minutes	Min 60
Final Setting Time	235 Minutes	
Free Lime	0.65%	

*All limits are according to Egyptian Standard Specifications 4756-1/2013

2.1.2 Coarse Aggregates

Local dolomite from natural sources was used in this research as a coarse aggregate with a nominal maximum size of 5 mm. The used coarse aggregate was clean, free of impurities, and with no organic compounds, as shown in **Figure** 1. **Table** 2 and **Table** 3 show the different physical properties and the sieve analysis of the used dolomite.

Figure 1: Coarse aggregate with size 5 mm.

Table 2: Physical properties of coarse aggregate

Test	Results	Specification Limit
Specific Gravity	2.63	------------------
Bulk density (t/m^3)	1.50	------------------
Materials Finer than Sieve no 200	0.40	Less than 3 % *
Abrasion (Los Anglos)	N. A	Less than 25 % *
Impact	N. A	Less than 30 % *
Flakiness index	15.20	Less than 40 % *
Elongation coefficient	14.25	------------------
Absorption	2.35	------------------

N.A: Not available test due to aggregate size.
*The limits according to Egyptian Standard Specifications

Table 3: Results of Sieve Analysis Test for Coarse Aggerate

Sieves Size (mm)	Passing %
50.00	100
37.50	100
20.00	100
14.00	100
10.00	99.95
5.00	95.26
2.36	0.76
1.18	0.28

2.1.3 Fine Aggregate

Fine aggregate, used in this research, is natural sand composed of siliceous materials. The fine aggregate was clean, free of impurities, and had no organic compounds. It had a grain size ranging from 0.15 to 5 mm and a fineness modulus 2.53. **Table 4** and **Table 5** show the different physical properties and the siliceous sand sieve analysis.

Table 4: Physical Properties of fine aggregate

Test	Results	Specification Limit
Specific Gravity	2.50	------------------
Bulk density (t/m^3)	1.71	------------------
Fineness modulus	2.53	------------------
Materials Finer than Sieve no 200	3.50	Less than 4 % *

*The limits according to Egyptian Standard Specifications 1109 / 2002

Table 5: Results of Sieve Analysis Test for Fine Aggerate

Sieves Size (mm)	Passing %
10.00	100
5.00	95.90
2.36	91.40
1.18	80.50
600	58.80
300	17.60
150	2.80

2.1.4 Fillers

Quartz is a powder form with Blaine fineness of 470 m2/kg, and a specific gravity of 2.63 was used as filler. The used quartz powder was a commercial product obtained from a local producer (see **Figure 3**). **Table 5** shows the chemical composition of the used quartz powder.

Figure 2: Quartz Powder

Table 6: Chemical composition of quartz powder.

Oxide	Content (%)
SiO_2	98.00
Fe_2O_3	0.01
Al_2O_3	0.25
CaO	0.50
MgO	0.20
K_2O	0.09
Na_2O	0.45
SO_3	0.20
H_2O	0.85

2.1.5 Silica Fume

Locally Produced Silica fume has been used in high-strength Concrete. It is a product resulting from the reduction of high-purity quartz with coal in electrical ore furnaces in the production of silicon. The fume, which has a high content of amorphous silicon dioxide and consists of very fine spherical particles, is collected from the gases escaping from the furnaces. Silica fume consists of very fine vitreous particles with a surface area 20000 m2/kg when measured by nitrogen adsorption techniques. Because of its extreme fineness and high silica content, the silica fume reacts with the lime during the hydration of cement to form the stable cementation compound. The availability of high-range water-reducing admixture has facilitated the use of silica fume as a part of the cementing material in concrete to produce high strength concrete. The normal silica fume ranges from 5 to 20 percent of Portland cement content.

It should be added to the mix to fill voids between the next larger class particles (cement particles), and increase the strength of the concrete. Upon adding this supplementary material, the strength of concrete may be increased by about 15-20%. The physical properties are shown in **Fig.3** and **Table7.**

Figure 3: Silica Fume.

Table 7: Physical Properties of Silica fume

Property		Test Result*
Physical Properties	Specific Surface Area (m^2/Kg)	10^3x17.8
	Particle Size (µm)	7.00
	Bulk Density (Kg/cm^3)	345
	Specific Gravity	2.15
	Color	Light Gray
Chemical Analysis by X-ray	% SiO_2	94.64
	% Fe_2O_3	0.93
	% Al_2O_3	0.97
	% CaO	0.55
	% MgO	0.35
	% SO_3	0.10
	%Lo I	2.01
	% Na_2O	0.20
	% K_2O	0.25
	% Cr	0.00

*By the manufacturer data sheet.

2.1.6 Water-reducing admixtures (HRWRA).

A commercially available (Super plasticizer – Sika Viscocrete®-3425) high-performance super-plasticizer was used to achieve the required workability for the produced concrete. The admixture meets the requirements for super-plasticizers type according to EN 934-2 [6]. Viscocrete®-3425 as an aqueous solution for modified Polycarboxylates. Its density is 1.08 kg/l. In this research, the dose of the super-plasticizer was selected based on the workability of the mix.

2.1.7 Steel Fibers

Steel fibers were added with a different dosage in some mixes to increase concrete ductility. The used fibers were commercially available and manufactured in corrugated circular segments with a length of 25 mm and a diameter of 1 mm, as shown in **Figure** 4. According to the manufacturer's datasheet, the fibers' properties comply with ASTM A820 [7] with an average tensile strength of 890 MPa.

Figure 4: Corrugated 25 mm steel Fibers.

2.2 Concrete Mixture

Detailed mixture proportions for all tested mixes are provided in Table 9. Twenty trial mixes were formulated in various proportions and utilizing natural coarse aggregates. Only eight mixes were chosen for further scrutiny and testing after initial evaluations. The desired compressive strength after 28 days was set at 80 and 120 MPa. For all mixtures, we used type I Portland cement and HRWRA. The aggregate for these mixtures were thoroughly washed and dried prior to use. Silica fume was used in all mixtures, and Steel fibers were used only in three mixtures.

Table 8: Mixture Proportions.

Mixture ID	Target Strength (MPa)	V_f (kg/m^3)	Quantity of material						w/c (%)	Curing
			Cement (kg/m^3)	Fine aggregate (kg/m^3)	Quartz Powder (kg/m^3)	Coarse aggregate (kg/m^3)	Silica Fume (kg/m^3)	Super-plasticizer (liter)		
G1-HSC80-A	80	-	450	685	-	1028	68	10	0.34	W
G1-HSC80-B	80	-	500	530	-	800	90	18	0.2	W
G1-HSC80-C	80	-	650	620	-	1120	60	20	0.28	W
G1-HSC80-D	80	-	650	620	-	1120	60	20	0.28	S
G2-HSC120-A	120	-	800	333	333	666	160	38.5	0.19	W
G2-HSC120-B	120	78.5	800	333	333	666	160	38.5	0.19	W
G2-HSC120-C	120	78.5	800	333	333	666	160	38.5	0.19	S
G2-HSC120-D	120	235.5	800	333	333	666	160	38.5	0.19	S

2.3 Preparation of Materials, Mixing, and Curing

Eight concrete mixtures were used in this experimental study, namely, High Strength Concrete (HSC) with different compressive strengths. Due to the low water-cement ratio (w/c) in HSC mixes, and to ensure homogeneity, a particular method of mixing was used: a mixer. First, fine materials (cement- silica fume – quartz powder) are added and drily mixed for 2 minutes. Then, fine aggregate is added to the mix, followed by the coarse aggregate, and the mixing continues for 2 minutes. Afterward, half of the amount of mixing water is added gradually to the fines, and the mixing continues for two minutes. Next, the super-plasticizer is added to the remaining water and then added to the mix. Mixing continues for three to four minutes till a homogenous paste is achieved. Then, fine aggregate is added gradually to the mix, followed by the coarse aggregate, which continues for 5 to 6 minutes. Steel fiber is added by scattering into the mix while mixing until the steel fiber is homogenously distributed in the mix, after pouring the concrete. Two systems of curing were used: water curing and steam curing. In water curing, after casting specimens in molds, the specimens were left to harden for 24 hours. Then, specimens were de-molded and submerged in a water temperature of about 20o C till the testing date. A steam curing tank was used to carry out the steam curing. The tank is an airtight tank equipped with a steam generator that sprays the steam from the bottom. The average temperature inside the tank was 70oC. After casting, specimens were left to harden for 24 hours. After removing specimens from the molds, they are transferred to the steam curing tank, and then the specimens were cured for seven days. After removing specimens from the steam tank, specimens were submerged in water at a temperature of 20^{o} C till the testing date.

3. Results and discussion:

For control purposes, the properties of hardened concrete were obtained for all concrete batches. According to ECP 203-17 standards, tests were conducted to determine each concrete mixture's compressive strength, tensile splitting strength, flexural strength, AND elastic modulus [8]. These tests are described as follows:

3.1 Compressive Strength Test

For each concrete mixture, twelve 150×150×150 mm cubes specimens and Twelve 150×300 mm cylindrical specimens were tested for their compressive strengths at the age of 7 and 28 days (the day of testing the reinforced beams), as shown in **Figure 5.** Three standard cured concrete cubes and three cylinders were tested at the age of 7 and 90 days to determine the actual compressive strength of the concrete. Of course, the most important mechanical property of used HSC is the compressive strength. After all, it is one of its prime attractions. The average compressive strengths of the three cubes and the average compressive strength of the cylinder at different ages are summarized in **Table 9.**

Cube Specimen

Cylindrical Specimen

Figure 5 : Test set-up for compressive strength test; (a) Cube specimen, (b) Cylindrical specimen

Table 9: Compressive strength of hardened concrete cubes and cylinders.

Mixture ID		Compressive Strength* (MPa)	
		7 days	28 days
G1-HSC80-A	Cubes	58	75
	Cylinders	-	64
G1-HSC80-B	Cubes	62	79
	Cylinders	-	70
G1-HSC80-C	Cubes	65	82.5
	Cylinders	-	72
G1-HSC80-D	Cubes	79	92
	Cylinders	-	78
G2-HSC120-A	Cubes	84	98.5
	Cylinders	-	81
G2-HSC120-B	Cubes	88.5	104.5
	Cylinders	-	86
G2-HSC120-C	Cubes	95	118
	Cylinders	-	96
G2-HSC120-D	Cubes	109	135.6
	Cylinders	-	112

*Average strength of concrete cubes (150 X 150 X 150 mm) and cylinders (D=150 mm, h=300 mm)

In discussing the first group, which comprises four concrete mixtures, evaluating performance against the target strength of 80 MPa reveals a mixed outcome. While the initial pair of mixtures failed to reach the specified strength level, the latter two mixtures successfully achieved or surpassed the target. Specifically, in the final mix designated as "G1-HSC80-D," a different curing method involving steam curing was utilized as opposed to "G1-HSC80-C." This adjustment in the curing technique resulted in a notable strength increase of approximately 11.5%, underscoring the significance of curing methods in influencing concrete strength outcomes.

For the second group, aiming for a compressive strength of 120 MPa, a series of varied variable were modified. Initially, introducing a steel fiber to the mixture resulted in a strength enhancement of approximately 6%. Subsequently, using a steam curing system for the existing mixture led to a significant compressive strength increase of about 13%, moving closer to the target strength. Finally, by increasing the quantity of steel fibers to three times the initial amount, a notable improvement of 15% in strength was observed compared to the previously attained level. These adjustments and additions in variables showcased promising progress towards reaching the desired compressive strength goal of 120 MPa and also it helped us to achieve a higher strength of 135.6 MPa.

3.2 Splitting Tensile Strength Test

Three concrete cylinders from each mixture with the same dimension as the compressive strength test were employed for the split tensile strength test. Specimens were tested at 28 days, as shown in **Figure 6.**

Figure 6: Test set-up for splitting tensile test.

The structural properties of concrete, such as the shear resistance, bond strength, and resistance to cracking, depend on the tensile strength. The higher the tensile strength is, the better the structural properties will be. The average Splitting tensile strength of the cylinder are summarized in **Table 3-11**.

Table 10: Average Splitting Tensile Strength.

Mixture ID	Splitting Tensile Strength (MPa)	Compressive Strength (MPa)	Fctr/Fcu %
	28 days	28 days	
G1-HSC80-A	5.5	75	7.3
G1-HSC80-B	5.7	79	7.2
G1-HSC80-C	6.3	82.5	7.6
G1-HSC80-D	7.4	92	8
G2-HSC120-A	8.25	98.5	8.3
G2-HSC120-B	10.5	104.5	10
G2-HSC120-C	11.5	118	9.8
G2-HSC120-D	16.3	135.6	12

*Average Splitting Tensile strength of concrete

In concrete mixes without steel fibers, the ratio between the average splitting tensile strength and the compressive strength falls within the range of 7.8% to 8.5%. However, when steel fibers were added, this ratio sees an improvement of around 12%. This enhancement suggests that incorporating steel fibers positively impacts the average tensile strength of concrete.

3.3 Flexural Strength Test

The modulus of rupture of concrete was determined by testing three 100 × 100 × 500 mm concrete beam specimens from each mixture. The beam specimens were tested at the age of 28 days. The three-point bending test setup is shown in Figure 7. The beams were loaded at a rate of 0.005 mm per second. This test focused on a critical parameter reflecting its tensile strength. The test involved conducting flexural strength tests on beam specimens to measure the maximum load at which failure occurred. Through analysis of the test results and calculations utilizing the dimensions of the beams, the modulus of rupture was determined. The average Flexural strength of the tested specimens is presented in **Table 3-11.**

Figure 7: Test set-up for flexural strength test.

Table 11: Flexural strength of concrete.

Mixture ID	Flexural Strength (MPa)	Compressive Strength* (MPa)	Fr/Fcu %
	28 days	28 days	
G1-HSC80-A	11.1	75	14.8
G1-HSC80-B	12	79	15.2
G1-HSC80-C	12.4	82.5	15
G1-HSC80-D	13.85	92	15.1
G2-HSC120-A	17.5	98.5	17.7
G2-HSC120-B	19.5	104.5	18.66
G2-HSC120-C	22.2	118	18.8
G2-HSC120-D	25.75	135.6	19

*Average Flexural strength of concrete

The findings reveal a noticeable pattern of the modulus of rupture rising in conjunction with higher compressive strength values. Specifically, the analysis demonstrates that as the compressive strength of the concrete samples progressed from 75 MPa to 135.6 MPa, we consistently observed an increase in the modulus of rupture from 11.1 MPa to 13.85 MPa.

3.4 Elastic Modulus Test

Three concrete cylinders from each mixture with the same dimension as the compressive strength test were used for the elastic modulus test. This test determines the chord modulus of elasticity of concrete cylinders when a compressive load is applied to a concrete cylinder in the longitudinal direction. The tested specimens are placed in the compressometer device parallel to the sample's vertical axis with the machine's longitudinal axis. The distance between the two yokes was 165 mm. Therefore, it should be placed at equal distances from both ends of the tested specimens, as shown in **Figure 8.**

The first stress was applied (σb = 0.5 MPa), and the corresponding displacement (ΔL) was determined. The applying stress will progressively increase with a constant rate of 0.5 MPa/sec up to max stress ($\sigma a = fc/3$). The applying stress will be constant for 60 seconds, recording the displacement in the gauge length during the next 30 seconds. The applied stress was then reduced to the lower stress at a rate of 0.5 MPa/s (σb = 0.5 MPa). It was also constant for 60 seconds, and displacement was recorded in the next 30 seconds. After that, the lower stress was maintained within the following 30 seconds. That will be repeated twice simultaneously during the loading and unloading cycle. After completing the loading cycle, the stress (σb) will be fixed for the 60s, and then in the next 30s, all the strains (εb) should be registered. After that, the application stress of the specimens is increased at the same rate mentioned before till it reaches (σa), and the corresponding strain (εa) will be measured in the next 30 seconds. The following equation can determine the modulus of elasticity

$$E= \Delta\sigma/\Delta\varepsilon = (\sigma a- \sigma b) / (\varepsilon a- \varepsilon b)$$

Figure 8: Test set-up for elastic modulus test

Table 11. summarizes the hardened properties of concrete corresponding to each test specimen, including the modulus of elasticity of each concrete mixture. The properties reported in this table were measured on 28 day after pouring the concrete.

Table 12: Flexural strength of concrete.

Mixture ID	Compressive Strength (MPa)	Splitting Tensile Strength (MPa)	Flexural Strength (MPa)	Elastic Modulus (GPa)
	28 days	28 days	28 days	28 days
G1-HSC80-A	75	5.5	11.1	25
G1-HSC80-B	79	5.7	12	26
G1-HSC80-C	82.5	6.3	12.4	27.2
G1-HSC80-D	92	7.4	13.85	30.6
G2-HSC120-A	98.5	8.25	17.5	37.7
G2-HSC120-B	104.5	10.5	19.5	39.3
G2-HSC120-C	118	11.5	22.2	42.3
G2-HSC120-D	135.6	16.3	25.75	46.5

We observed a correlation between the elastic modulus test results and the compressive test results, noting a slight increase between the mixtures in the first group except the last one. In the first group, the impact of steam curing was evident, as it appeared to enhance the cement hydration process noticeably.

In the second group, we observed a distinct effect on the elastic modulus results attributed to the presence of fiber volume in the concrete mixture. This additional component seemed to further enhance the elastic modulus values in this group.

4. Conclusions

The extensive examination of concrete mixes incorporating varying curing methods and steel fiber volumes uncovers a subtle interplay between these elements and the resulting mechanical characteristics. These results suggest the strategic incorporation of steam curing and steel fiber in concrete mix designs, presenting a sustainable approach that aligns with structural design objectives without inflating costs. Optimization of these mixes for practical applications remains critical, emphasizing a balance between ecological benefits and mechanical demands. Future studies should concentrate on improving the mechanical characteristics of concrete, which has the potential to significantly boost the sustainability and resilience of concrete structures, leading the industry towards more environmentally friendly construction options.

This paper summarizes several steps in the development of HSC using local materials. The conclusions drawn during the work were:

1. HSC was developed with materials locally available in Cairo, Egypt, that produced a compressive strength of 135.6 MPa and a flexural strength of 25.75 MPa.
2. The technology to produce this type of concrete is based on eliminating the coarse aggregates and using coarse fine aggregate

3. . Using the quartz powder as a replacement of the sand content improved the compressive strength; this was attributed to the filling ability of the fine quartz materials
4. The compressive strength exhibited an upward trend with the increase in cement content up to 650 kg/m3, as anticipated. However, it was noted that the mixture containing 500 kg/m3 showed either the same value or a slight decrease compared to the former. This occurrence can be attributed to the higher proportion of cement paste in relation to aggregate content in the mix, a factor typically influencing mechanical strength.
5. The application of atmospheric pressure steam curing systems greatly increases the hydration rate to raise the early strength of concrete, achieving the designed strength within 7 days of casting.
6. The presence of steel fibers in concrete can notably influence its compressive strength. By serving as reinforcement within the concrete, steel fibers enhance its toughness, durability, and ability to resist cracking when subjected to compressive forces. This incorporation boosts the performance and longevity of concrete structures, enhancing their capacity to endure increased levels of compressive stress.
7. Steel fibers enhance concrete's tensile strength: the ratio of splitting tensile strength to compressive strength improves by approximately 12%
8. The modulus of rupture increases with higher compressive strength, from 75 MPa to 135.6 MPa, and rupture rises from 11.1 MPa to 13.85.
9. The increase in elastic modulus is observed in mixtures with higher compressive strength, which is the expected behavior. Furthermore, the steel fiber significantly affects the enhancement of the elastic modulus.

References

[1] M. A. Caldarone, *High-strength concrete: a practical guide*. CRC press, 2014.

[2] F. De Larrard and T. Sedran, "Optimization of ultra-high-performance concrete by the use of a packing model," *Cem Concr Res*, vol. 24, no. 6, pp. 997–1009, 1994.

[3] B. A. Graybeal, "Material property characterization of ultra-high performance concrete," United States. Federal Highway Administration. Office of Infrastructure …, 2006.

[4] S. Collepardi, L. Coppola, R. Troli, and M. Collepardi, "Mechanical properties of modified reactive powder concrete," *ACI Special Publications*, vol. 173, pp. 1–22, 1997.

[5] A. S. Dili and M. Santhanam, "Investigations on reactive powder concrete: A developing ultra high-strength technology," *Indian concrete journal*, vol. 78, no. 4, pp. 33–38, 2004.

[6] B. S. EN, "934-2 Admixtures for Concrete, Mortar and Grout," *British Standards Institute: London, UK*, 2009.

[7] A. Astm, "Standard specification for steel fibers for fiber-reinforced concrete," *American Society for Testing and Materials (ASTM) Committee*, 2006.

[8] *Egyptian Code of Practice for Standard Test Methods of Concrete Materials*, Third edit. Giza, Egypt: Egyptian National Housing and Building Research Center, 2007.