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Characteristics of Ultra-High-Strength Self-Compacting Concrete (UHSSCC) Containing Macro Steel, Polypropylene Fibers and Local Materials

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Abstract: Self-Compacted Concrete (SCC) structure has been widely utilized in high-rise buildings and long-span structures owning to the advantages of high bearing capacity, good seismic performance, and superior corrosion resistance. The current investigation is aimed at developing strengths of (SCC) to more than M 120 Grade with keeping its requirements of workability such as flowability, passing ability and segregation resistance. These properties have been examined by using slump flow, L-box, V-funnel respectively. This study includes achieving acceptable grade of concrete by finding the ultimate mechanical strengths and fresh properties of self-compacted concrete by using locally materials and available in local markets. Also, Ultrasonic Pulse Velocity (UPV) test and sorptivity test were performed. To achieve the purpose, 12 mixes were performed and divided to groups. Group (1) only fine aggregate is used. Group (2), quartz powder (QP) was used as a filler material by 26% replacement from sand. Each group include, Silica Fume (SF) and Metakaolin (MK) as a pozzolanic replacement material by percentages (SF/MK) (22% - 0% and 11% - 11%) respectively. In addition to two types of fiber were used (steel and polypropylene fiber) by (0-160) kg/m3 and (0-1.8) kg/m3 respectively as reinforcing materials The results indicate that local material can produce ultra-high strength self-compacted concrete more than 120 Mpa. Steel fiber and polypropylene fibers improved compressive, tensile and flexural strength. Using polypropylene fiber decrease sorptivity coefficient due to high amount of porosity. This result shows significant reduction in capillary porosity and inner conductivity of pores by using fibers.

Keywords: Self Compacted Concrete, Steel Fiber, Polypropylene Fiber and sorptivity..

1. INTRODUCTION

Construction of high-rise structures and megaprojects around the world has boosted demand for high-strength concrete (HSC), as have the demands of owners and designers (HSC). It's worth noting that the definition of HSC has evolved over time and will very certainly continue to evolve. In the last thirty years, advances in concrete science and technology have greatly outpaced those made in the previous 150 years. UHSC (ultra-high-strength concrete) is a new type of concrete. It was a product of this progression. This innovative concrete type has a very high compressive strength of more than 100 Mpa. [1]. High-strength concrete building parts are typically heavily reinforced. This density in the reinforcing causes serious issues while pouring concrete. This challenge can be solved by using self-compacted concrete that can be easily laid and disseminated across congested reinforced concrete pieces. This form of concrete ensures a highly homogeneous, evenly distributed, and dense concrete. SCC was created in the 1980s at the University of Tokyo in Japan with the assistance of renowned concrete contractors, especially for use in densely congested reinforced structures in seismic zones. Because the endurance of concrete constructions was a major concern in Japan, trained workers exerted appropriate pressure to achieve durable concrete structures. SCC was created in response to this need. [2]. The development of SCC was first reported in 1989. Self-compression is based on the principle that the settling velocity of a particle is inversely proportional to the viscosity of the medium in which the particle is located. It mainly flows under gravity, i.e. under its own weight. It can be possible produced in high strength with ordinary concrete. But it cannot flow under its weight to reach every corner of the formwork in case densely reinforcement, the engineering of high-strength concrete elements thorough compaction and vibration in construction process. The development of SCC is a highly desirable achievement in the construction industry to overcome the problem with cast-in-place concrete. The possibility of manufacturing various by-products in its manufacture. The use of SCC is limited to the construction period, also guarantees the quality and durability. It replaces the manual compaction of concrete with a state-of-the-art semi-automatic placing technology [3]. The use of fiber in concrete considerably minimizes brittle fracture, and the behavior of fiber-reinforced concrete will be ductile under diverse pressures, particularly compressive, tensile, and blast stresses. The fibers tend to sustain the integrity of the concrete up to considerable deformation by bridging across the edges of the cracks, preventing brittle collapse. Fiber reinforced concrete is being employed in a variety of applications such as road walkways, high-rise buildings, bridges, and tunnels. [4]. By the addition the fibers, the load displacement behavior can be improved and thus improve the ductility and fracture toughness. This can be attributed to the fact that the fibers are able to transmit the loads arising by sealing the cracks. Using the fibers to produce Ultra High Strength Fiber Reinforced Concrete (UHS-FRC) will enable structures to gain innovative features and open up new areas of UHSC application [5]. [6] stated that the incorporation of different attribute types of steel fibers significantly improved the mechanical properties of the concretes, without depending on the incorporation of metakaolin and w/b ratio. The research by [7], presented the properties of SCC and FRSCC in the fresh and hardened states. The mechanical properties including compressive and splitting tensile strengths, modulus of elasticity and modulus of rupture are improved as a result of fiber addition. The results of [8], showed that steel fibers can enhance the mechanical properties of concrete, according to research. However, a higher fiber content does not always result in an increase in compressive strength. The characteristics of concrete containing fly ash and steel fibers were studied by [9]. Steel fiber addition to Portland cement or fly ash concrete improved tensile strength, drying shrinkage, and freeze–thaw resistance, but did not significantly improve final compressive strength, according to the findings. The influence of matrix strength, fiber content, and diameter on the compressive behavior of SFR concrete was examined by [10]. The fibers improved toughness but reduced elasticity modulus marginally, according to their findings. Furthermore, the compressive strength is important. The compressive strength of SFR concrete is mostly determined by the mix properties, not just the fiber type and amount. [11] found similar results to [12], but their study additionally looked at the impact of marble powder replacement on the fresh and hardened properties of SCC with various lengths of steel fibers. [13–15] proposed the first known approach of mix design in 1993, which was later modified in 1998 with the help of [16].

The main objective of present investigation is, development of properties of SCC with local material and available in local market to achieve ultra-high strength more than 120 Mpa.

2. METHODOLOGY

Start point was Adley Mansour Bridge Figure 1 that constructed on Nile River at Beni Suef governorate-Egypt, where the used mix (SCC) has compressive strength 600kg/cm2, its component was recorded in Table 1. In this mix crushed dolomite with maximum nominal size 10 mm, CEM I (42.5) was used, silica fume produced by SIKA Co. was used by percentage (S.F/B) 10% and Master Glenium C 315 superplasticizer provided by BASF Co. was used as a high range water reducer admixture with ratio 1.4%. Some trails and modifications were performed on the previous mix to increase the compressive strength, as increase cement from 475 to 600 kg/m3, increase (S/B) ratio from 10% to 20%, decrease W/B from 0.30 to 0.20 latterly, decrease maximum nominal size from 10 mm to 5 mm but the maximum obtained strength was 750 kg/cm2, so to achieve ultra-high strength shall elimination the C.A and using mortar concrete with fiber to produce Ultra-High Strength Mortar Self-Compacted Concrete (UHSMSCC).

Figure 1 Adly Mansour Bridge

Table 1 Concrete Mixes Component (Kg/m3) (Adly Mansour Bridge)

C	S	B	C.A	F.A	W	S.P	W/C	W/B	S.F/C	S.F/B	S.P/C	S.P/B
475	50	525	950	830	156	7.5	33%	30%	11%	10%	1.6%	1.4%

C=Cement, S=Silica Fume, B= Total binder CA= Dolomite Coarse Aggregate, FA=Fine Aggregate, W=Water, SP=Superplasticizer

3. EXPERIMENTAL PROGRAM

3.1 RAW MATERAILS

The three binder materials were used in this study namely Cement CEM I 52.5, Silica Fume, and Metakaolin were locally provided. Both SF and MK are used as a pozzolanic cement replacement material (Type II). Quartz powder (QP) was used as a fillers material to partially replace sand to optimize the packing density of SCC and hence reduces the paste volume. Quartz powder was produced from grinding pure sand with high SiO2 content from Suez Company for minerals. All binder and powders characteristics are listed in Table 2. To achieve SCC requirements a Master Glenium C 315 superplasticizer provided by BASF Co. was used as a high range water reducer admixture with a specific gravity of 1.08. Natural sand with the water absorption, specific gravity, and maximum grain size of 0.65%, 2.81, and 2.36 mm, respectively was used. The grading of the used material is presented in Figure 2. In this study, two types of fiber were used corrugated steel and polypropylene fiber. Figure 3 and Table 3 show the shape and properties of these fibers. Tap water was used in the mixing and curing process.

3.2 CONCRETE MIX DESIGN

The experimental program was built based on reference mixes identified from a series of trials by the authors to produce a mix design with a combination of ultra-high strength and specifies fresh SCC characteristics.Table 4 shows 12 mixes designed to have Ultra High Strength Mortar Self Compacted Concrete (UHSMSCC) of grade (100-127) Mpa.

All these concrete mixes have the same binder content of 1098 kg/m3, where cement content 900 kg/m3 and constant water binder ratio 20%. The twelve mixes are divided into 2 groups. The first group (G1) is a control group, where sand was used as fine aggregate only.

Table 2 Chemical composition and Physical properties for the used SCM materials

Compound (%)	C	SF	MK	QP
SiO_2	21.20	96.0	55	99.20
AL_2O_3	5.50	0.10	42.7	0.35
Fe_2O_3	3.20	1.0	1.40	0.04
CaO	63.4	0.20	0.30	0.15
MgO	0.70	0.15	0.30	0.02
SO_3	2.40	0.10	0.01	---
Na_2O	0.10	0.10	0.30	0.01
K_2O	0.50	0.20	0.0	0.01
loss on ignition	3.00	2.15	0.90	0.2
Color Powder	Gray	Light Gray	Light Beige	white
Grain Size	90 µm	1 µm	0.50 µm	45 µm
Specific Gravity	3.15	2.15	2.5	2.70
Bulk Density (t/m^3)	1.51	0.355	1.2	1.28

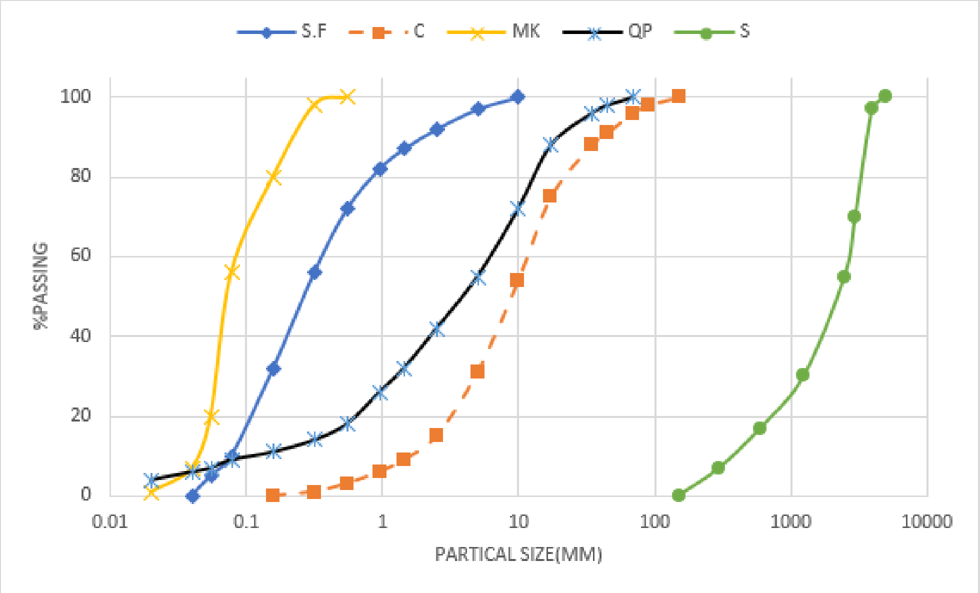
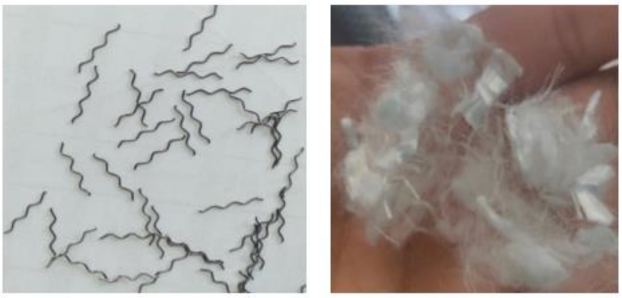


Figure 2 Particle Size Distribution of the used material



Steel fiber Polypropylene fiber

Figure 3 The used fibers

Table 3 Characteristics of Steel and Polypropylene fiber

Properties	**Steel fiber**	**Polypropylene fiber**
Tensile stress	2500 Mpa	350 Mpa
Modulus of Elasticity	205 Gpa	3.5 Gpa
Density	7.8 t/m^3	0.91 t/m^3
Diameter	0.2 mm	0.018 mm
Length	12 mm	9 mm
Aspect ratio	60	500

Group (G2), the sand was replaced by 26% Quartz Powder (QP). Each group has two ratios of SF/MK (22%-0% and11%-11%) respectively and with pozzolanic material steel and polypropylene fibers were used by quantities (0, 160) kg/m3 and (0-1.8) kg/m3 respectively. The total weight of mixes was between (2404 to 2477 kg/m3). Total content of sand, QP and fibers = 1050 kg/m3.

3.3 MIXING, CASTING AND CURING PROCESS

The mixing process was performed using pan concrete mixer of 10 liters capacity as shown in Figure 4. The mixture components weighted carefully then, the solid component (sand and cement) mixed to obtain homogenous mix. Pozzolanic material (SF, MK) and fibers were added to the mix. The water and the super plasticizer mixed then added to the dry contents in the drum then mixed till the mixture is in suitable consistency to be cast (time of mixing differ from mix to the other according to mixtures components). Each mold was filled with concrete in two layers and each layer was lightly vibrated to remove air voids. After finishing the concrete surface specimens were covered by plastic sheets to prevent water evaporation. After 48 hours the specimens were demolded and cured in water tank (25 oC) for 90 days.

Table 4 Concrete Mixes Components (Kg/m3)

M#	G#	*Code	C	S	MK	B	F. A	QP	W	W/B	S. P	S.P/B	ST. F	PP. F
1	G# 01 (Sand)	S22-M0-ST0-PP0	900	198	0	1098	1050	0	219.6	20%	36.2	3.3%	0	0
2		S11-M11-ST0-PP0	900	99	99	1098	1050	0	219.6	20%	38.4	3.5%	0	0
3		S22-M0-ST160-PP0	900	198	0	1098	890	0	219.6	20%	37.3	3.4%	160	0
4		S11-M11-ST160-PP0	900	99	99	1098	890	0	219.6	20%	39.8	3.6%	160	0
5		S22-M0-ST0-PP1.8	900	198	0	1098	1048.2	0	219.6	20%	37.3	3.4%	0	1.8
6		S11-M11-ST-0-PP1.8	900	99	99	1098	1048.2	0	219.6	20%	40.6	3.7%	0	1.8
7	G# 02 (Sand + Quartz)	S22-M0-ST0-PP0	900	198	0	1098	780	270	219.6	20%	39.0	3.6%	0	0
8		S11-M11-ST0-PP0	900	99	99	1098	780	270	219.6	20%	39.5	3.6%	0	0
9		S22-M0-ST160-PP0	900	198	0	1098	620	270	219.6	20%	40.1	3.7%	160	0
10		S11-M11-ST160-PP0	900	99	99	1098	620	270	219.6	20%	40.6	3.7%	160	0
11		S22-M0-ST0-PP1.8	900	198	0	1098	778.2	270	219.6	20%	41.7	3.8%	0	1.8
12		S11-M11-ST-0-PP1.8	900	99	99	1098	778.2	270	219.6	20%	42.8	3.9%	0	1.8

M#=Mix number, G#=Group number, C=Cement, S=Silica Fume, MK=Metakaolin, B=Total Binder, FA=Fine Aggregate, QP=Quartz Powder, W=Water, W/B= Water Binder Ratio, S.P=Superplasticizer, S.P/B=Superplasticizer Binder Ratio, ST. F= Steel Fiber, PP. F=Polypropylene Fiber,
*(S22-MK0-ST0-PP0)=% Silica Fume - % Metakaolin - Steel fiber quantities - Polypropylene quantities.

Figure 4 Concrete Mixer

4. TEST PROCEDURES

4.1 FRESH CHARACTERISTICS

All workability Tests of self-compacted concrete were performed on the all following SCC mixes and achieved all requirements of European SCC Guidelines [17] that recorded in Table 5. The diameter of the fresh SCC was measured in two directions and the average diameter was recorded as slump flow diameter. Passing ability of fresh concrete was estimated using L-box test, where the fresh SCC in the vertical box was allowed to flow through the bars to the horizontal box. When the mixture flow stopped, the aspect ratio (h2/h1) was determined to evaluate the passing ability of SCC. V-funnel flow test used to describe the filling ability and Segregation Resistance characteristic of the SCC mixtures based on the flowing rate. The time measured in the V-funnel flow test is the elapsed time between the beginning and end of flowing of SCC from the funnel.

Table 5 Requirements European SCC Guidelines

Property	Tests	Code Limit
Filling ability	Slump Flow	600-800 mm
	V-funnel	6-12 sec
Passing ability	L-box	h2/h1= 0.8-1
Segregation Resistance	V-funnel after 5 minutes	(t_0-t_5) = 0-3 sec

4.2 MECHANICAL PROPERTIES

Compressive strength test was performed on 3 cubes of 5x5x5 cm3 for each concrete mix according to ASTM C109 [18]. Using ELE digital testing machine of 2000-ton maximum capacity, the specimens were tested at 90 days. Splitting tensile strength was examined on 3 cylindrical specimens of 5 cm diameter and 10 cm height for each concrete mix according to ASTM C496 [19]. Flexural strength was examined on 3 prism specimens of 4x4x16 cm for each concrete mix according to ASTM C293[20] . The beams were tested on a 160 mm span for a 40 mm depth specimen with one load applied at the midpoints. A central point load was applied to a beam supported by steel rollers to obtain these loads. The load was gradually raised until the beam finally gave way. The sample's flexural tensile strength was calculated based on the kind of failure, fracture appearance, and fracture load.

4.3 NONDESTRUCTIVE TEST (ULTRASONIC PLUS VELOCITY TEST)

Ultrasonic pulse velocity test basically involves the measurement of electronic wave velocity through concrete. Ultrasonic pulse velocity test was conducted on 100 mm cube in accordance with ASTM C597 [21]. This test is used to assess the concrete quality.by recording the time required for the wave to pass throw concrete cube between transmitter and receiver by knowing the cube dimension as shown in Equation 1.

$$\mathbf{V=L/T} \qquad \mathbf{(1)}$$

Where, L is the side length of cube in mm and T time recorded in µ sec

4.4 DURABILITY (SORPTIVITY)

For each of the concrete mixtures, disk diameter 100 mm and height 50mm to measure Water absorption (sorptivity) by capillary action were cast. Sorptivity was measured for all the mixes under different curing conditions after 90 days in accordance with ASTM C1585 [22]. To achieve a nearly constant mass, the specimens were dried in an oven for three days at a temperature of 50 °C. The slices were then sealed in bags for minimum 15 days. The specimens were weighted. Then the samples were coated with paraffin wax around side surfaces except the base to prevent any water from getting absorbed through the sides of the specimens. The samples were placed in a constant water depth, of 2-3 mm above the bottom of the specimen, to allow water absorption by capillary action. Mass change after semi-immersion for one hour was measured and the sorptivity was calculated as follows in Equation 2.

$$\mathbf{I=A*St^{0.5}} \qquad \mathbf{(2)}$$

Where:

I, represents the change in weight before and after testing in grams

A, represents the exposed area of the specimens in mm^2 (area =7854 mm^{2}for the test samples)

S, represents the sorptivity in gm/mm^2/sec$^{1/2}$

t, is the testing time, measured in second (3600 sec).

5. RESULTS AND DISCUSSIONS

5.1 FRESH PROPERTIES OF UHSMSCC

In this studythe amount of superplasticizer added for each concrete mix slightly increases with increasing the amount of active and inert powders (S, MK, QP) to specify SCC workability requirement according to European SCC Guidelines [17]. So, in this study SF/MK by 0%-22% respectively was trailed, but the mount of superplasticizer was more than optimum dosage (4%) according to manufacture data. So, these mixes were neglected. Also, all mixes which have the same binder type and content, flowability and passing ability in terms of decrease in slump flow diameter, increase in time in V-funnel and decrease in h2/h1 ratio in L-box. Workability of

UHSMSCC mixes gradually decreased with incorporating QP as a sand replacement. However, rheological classes are not affected due to their practically wide limits. As shown in Table 6, S.F improves the workability for all mix, although using MK by 11% replace from silica fume decrease the workability by 12%.This effect can be attributed to the higher specific surface area of MK compared to SF, as well as the irregular or plate like shape of MK particles are considered to be the two main factors for the loss of both flowability and passing ability and the increase in viscosity [23,24].

The significant higher reduction in rheological properties due to MK inclusion is reflected on rheological classes, also using QP by 26% replace from sand decrease workability by 4% due to the higher water demand due to the decreased particles size and the increased specific surface area of both MK (< SF) and QP (< sand). A similar effect has been reported in previous literature [23, 25]. Notably, a negative significant impact of rheological characteristics as a function of SF replacement level by MK in UHMSCC is observed. Finally using steel and P.P fibers decrease the workability due to, incorporating fibers made the SCC generally less viscous, and addition of fibers to SCC led to a decrease in the workability, indicating that fibers do not allow aggregates to move freely [12].

5.2 COMPRESSIVE STRENGTH (CS)

As shown in Figure 5 and Table 7 obviously, the compressive strength of control specimens containing different active and inert powder as a cement replacement. Clearly noticed in each group thatreplacing SF by 11%MK has the higher compressive strength than 22%SF concrete in the same group by (9.1-13.3%). The enhanced compressive strength of MK blended UHSMSCC is mainly due to quick pozzolanic reaction of MK with calcium hydroxide, the acceleration of OPC hydration as well as its higher micro-filler effect due to its high surface area [26] Moreover, the mixtures having QP powder possess higher compressive strength, irrespective of the presence of active powder (MK or SF). The mixtures in G2 have higher compressive strength than corresponding mixtures in G1. By comparing the mixes, the results indicate that `QP inclusion has better contribution to compressive strength of UHSMSCC and clears that replacing 26% sand with QP somewhat increase compressive strength by 3-4%. It is well known that the improved mechanical and durability properties of concrete containing fine powder (QP) could be attributed to the its pore-filling effect resulting densified and more compacted microstructure [23]. Additional to, using steel fiber improve strength by 19.1-23.1% and P.P fiber instead of steel fiber improve compressive strength by 10.6-11.4%. The increased compressive strength of the concrete mixtures with fibers can be attributed to the reduced growth of cracks, which is dependent on the bond strength (confinement effect) of the steel fiber [29].

5.3 SPLITTING TENSILE STRENGTH (STS)

Figure 5 and Table 7 shows the splitting tensile strength of specimens for all studied concrete mixtures. It can be seen that splitting tensile strength (STS) follows a similar trend as compressive strength trend. The results reported that inclusion of 11% SF and 11% MK improve STS by 6-9%. By using QP by 26% replacement sand improve the STS by 4.1-6% this due to, (QP) could be attributed to the its pore-filling effect resulting densified and more compacted microstructure [28]. Also, steel fiber and polypropylene fibber improve tensile strength for SCC by 33.3-36.7% and 23.9-24.7% respectively. As shown in Figure 6, this fiber enhancement due to Fiber content can improve the tensile strength characteristics because it hinders and bridges the cracks of the concrete matrix, and the bridging force particularly depends on the selected fiber type [30]. Also, as recorded in Table 7 the average ratio of splitting tensile strength related to compressive strength 9.5%.

Table 6 Fresh properties

M#	G#	Code	Slump Diameter (mm)	(T_0), sec	h_2/h_1	(T_0-T_5), sec
1	G# 01 (Sand)	S22-M0-ST0-PP0	795.0	6.00	0.97	7.5
2		S11-M11-ST0-PP0	707.6	7.00	0.94	8.75
3		S22-M0-ST160-PP0	715.5	10.00	0.88	10
4		S11-M11-ST160-PP0	615.6	11.50	0.85	11.25
5		S22-M0-ST0-PP1.8	755.3	6.50	0.91	12.5
6		S11-M11-ST-0-PP1.8	636.8	7.20	0.89	14.375
7	G# 02 (Sand + Quartz)	S22-M0-ST0-PP0	760.0	8.00	0.92	13.75
8		S11-M11-ST0-PP0	668.8	9.00	0.9	15
9		S22-M0-ST160-PP0	679.7	11.00	0.83	8.125
10		S11-M11-ST160-PP0	611.8	12.00	0.8	9
11		S22-M0-ST0-PP1.8	638.9	8.30	0.88	10.375
12		S11-M11-ST-0-PP1.8	562.3	9.20	0.87	11.5

Table 7 Mechanical Properties

M#	G#	Code	(CS) (Mpa)	(STS) (Mpa)	(FS) (Mpa)
1	G# 01 (Sand)	S22-M0-ST0-PP0	91.83	7.95	17.4
2		S11-M11-ST0-PP0	104.02	8.53	19.6
3		S22-M0-ST160-PP0	113.01	10.59	24.8
4		S11-M11-ST160-PP0	123.88	11.48	27.3
5		S22-M0-ST0-PP1.8	102.27	9.96	23.64
6		S11-M11-ST-0-PP1.8	115.21	10.56	26.12
7	G# 02 (Sand + Quartz)	S22-M0-ST0-PP0	95.50	8.29	18.8
8		S11-M11-ST0-PP0	107.15	8.90	21.4
9		S22-M0-ST160-PP0	116.96	11.16	26.7
10		S11-M11-ST160-PP0	127.60	12.16	29.1
11		S22-M0-ST0-PP1.8	105.61	10.37	25.1
12		S11-M11-ST-0-PP1.8	119.12	11.10	28.1

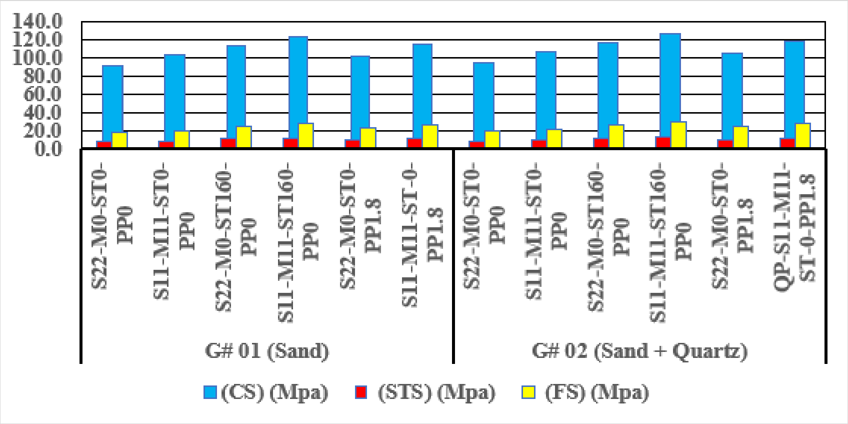


Figure 5 Mechanical Properties

5.4 FLEXURAL STRENGTH (FS)

Figure 5 and Table 7 shows the splitting tensile strength of specimens for all studied concrete mixtures. The results shows that inclusion of 11% SF and 11% MK improve FS by 8.9-13.5% this improvement due to quick pozzolanic reaction of MK with calcium hydroxide, the acceleration of OPC hydration as well as its higher micro-filler effect due to its high surface area [26].By using QP by 26% replacement sand improve the FS by 6.4-9.1% this due to, (QP) could be attributed to the its pore-filling effect resulting densified and more compacted microstructure [28].

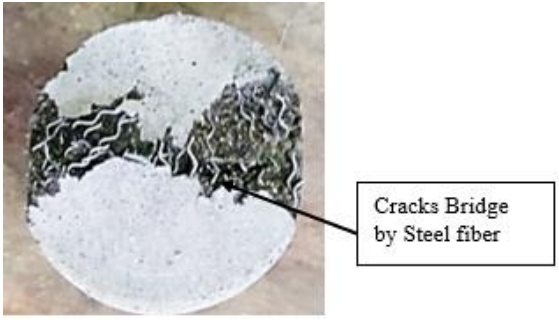


Figure 6 Failure and fracture surface of Splitting Tensile Strength (Steel Fibers samples)

Also, steel fiber and polypropylene fibber improve flexural strength for SCC by 36.2-42.5% and 33.5-35.8% respectively. This fiber enhancement due to Fiber content can improve the tensile strength characteristics because it hinders and bridges the cracks of the concrete matrix, and the bridging force particularly depends on the selected fiber type [30]. As the given Figure 7, the concrete matrix showed micro cracks. With the development of macroscopic cracks, the cracks of the concrete matrix continued to expand. In the process of pulling out gradually at this time, steel and polypropylene fibers works on connecting the concrete across these cracks. The fibers concrete mixes showed better ductility in the presence of fibers across the cracks, and they increased the capability of transferring the stress. In the fracture process zone, micro cracks were fully developed, and the absorbed external load energy increased. The steel and polypropylene fibers increased the bridging effect, and achieved a comparatively good ductility. Also, Table 7 shows that, the average ratio between flexural strength and compressive 19.5%.

Finally, M# 10 which contains SF/MK = 11-11%, steel fiber and QP achieve the best results for CS, STS and FS (127.6-12.2-29.1Mpa) respectively.

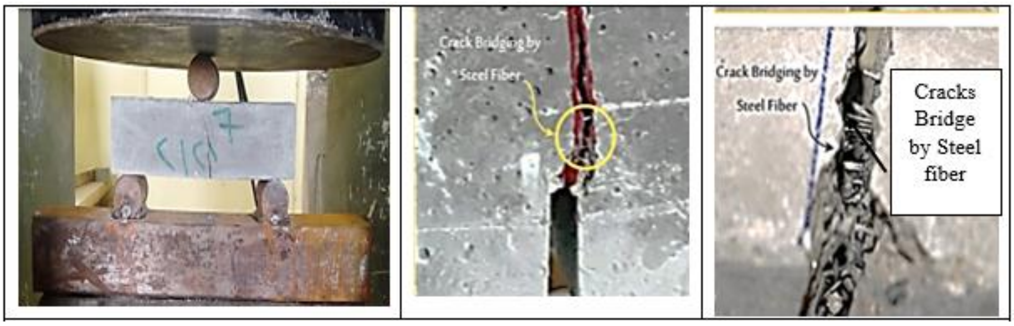


Figure 7 Failure and fracture surface of Flexural Strength (Steel Fibers samples)

5.5 UPV

UPV test results are shown in Figure 8 for all designed UHSSCC When considering the quality of all mixes in terms of UPV values, IS 13311(part 1)-1992 gives the range of UPV rating for expressing the quality of concrete – for excellent quality of concrete the UPV shall be greater than 4500 m/s; for good concrete the UPV shall be 3500 – 4500 m/s; for fair or medium concrete the UPV shall be 3000 – 3500 m/s, and for poor concrete UPV shall be less than 3000 m/s. It can be seen that all mixes, can be classified as excellent quality concrete. Packing density, high strength, low pores are the main reason for high velocity and superior properties of on destructive concrete properties [31, 32].

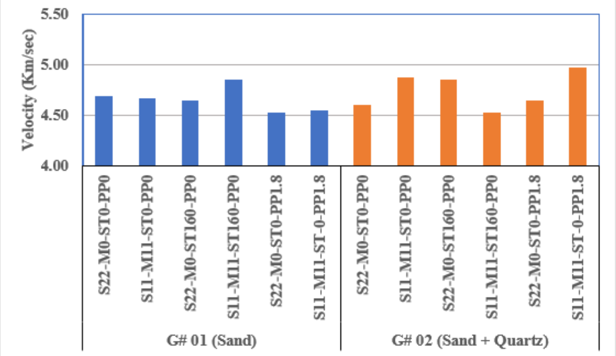


Figure 8. UPV for UHSSCC

5.6 DURABILITY (SORPTIVITY)

In this investigation, water sorptivity is evaluated as an indicator for durability of concrete. In the test method, a concrete sample is partially immersed in water within a container. The main force that absorbs the water inside the concrete sample is the capillary suction which depends mainly on the number and continuity of capillary pores. The mass increase in every sample is recorded with time and the sorptivity coefficient can be presented in Figure 9. Using SF/MK by11-11% and replace the sand by 26% decrease sorptivity coefficient by 7.8% and 4.4% respectively due to the developed Self-compacting concrete (SCC) is classified with as UHPC which have dense microstructure and lower porosity according to concept of packing theory [33]. Using polypropylene fiber increase sorptivity coefficient by 14% due to increasing in capillary porosity and inner conductivity of pores by using fibers [34].

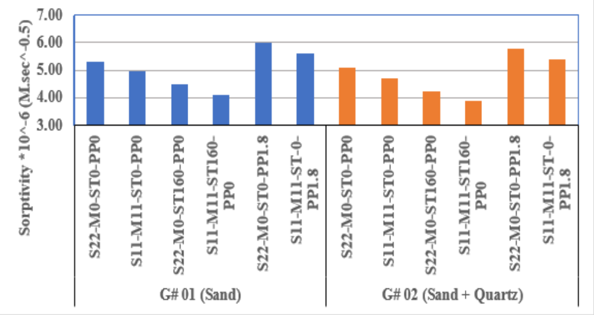


Figure 9 Sorptivity for UHSSCC

6. CONCLUSIONS

- It was observed that the rheological properties defined for the mortar phase were suitable for obtaining the desired rheological properties in concrete phase. The results showed that the correlation between the rheological properties of mortars and concretes should be evaluated under similar test conditions.
- The Egyptian code does not have mix-design criteria for SCC above 120MPa. In this study we have vision to achieve an ultra-high strength SCC and have all requirements of self-compacted concrete.
- A compressive strength of 127 MPa, indirect tensile strength of 12.16 MPa, and flexural strength of 29.1 MPa were achieve for samples of 900 kg/m3 cement content, 11% silica, MK11% fume/cement, and 26% quartz/cement and steel fibers 160 kg/m3 (mix no. 8).
- Addition of quartz powder to SCC led to improve the mechanical properties.
- Addition of fibers to SCC led to a decrease in the workability.
- Compressive, Splitting and Flexural strength were improved by utilization of steel fibers and polypropylene fibers.
- The UPV test results for all studied mixes can be classified as excellent concrete, since the UPV values exceed 4500 m/s.

- Using polypropylene fiber increase sorptivity coefficient by 14% due to increasing in capillary porosity and inner conductivity of pores by using fibers.

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