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PRODUCTION OF ULTRA HIGH-STRENGTH CONCRETE USING LOCAL MATERIALS

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ABSTRACT

The current research intends to study the possibility of producing ultra high strength concrete using local materials in the Egyptian market. The effect of silica fume, quartz powder, steel powder, steel fibers, type and dosage of superplacitizers were investigated in forty nine different concrete mixes. The effect of the variables were considered and investigated. Three percentages of silica fume (10%, 15% and 20 %) were applied as a replacement of cement content. Quartz powder with a percentage of 10% of sand content was considered. Steel Powder with a percentage of 10 % of sand content was used. Also, different types of high range water reducer ranged from (0.5 to 2%) by weight of powder (cement and filler) were used. The weight of the steel fibers was 40 and 80 kg/m^3.The water content was determined by trail mixes and the water-to-powder ratio (w/p) was in the rang of (0.2 - 0.45). The results indicated the possibility of using local materials in the Egyptian market in producing ultra high strength concrete. The use of 10% silica fume as a replacement of cement content and 30% water per powder resulted in compressive strength after 3, 7 and 28 days 43 MPa, 67.4 MPa and 127 MPa, respectively. Moreover, using the steel fibers with 40 kg/m^3 increased the compressive strength 64.3 Mpa, 88.0 Mpa, and 135 MPa at 3, 7 and 28 days, respectively

يهدف هذا البحث الى دراسة إنتاج خرسانة فائقة المقاومة وذلك بإستخدام المواد التقليدية والمحلية المتوافرة فى السوق المصرية إمكانية إنتاج خرسانة فائقة المقاومة بإستخدام المواد المحلية المتوافرة فى السوق المصرية. تم صب عدد تسعة وأربعون خلطة خرسانية باستخدام نسب خلط مختلفة للوصول الى المقاومة المطلوبة. تم دراسة تأثير استخدام غبار السليكا (١٠، ١٥ ، ٢٠% كإحلال من وزن الأسمنت) بودرة الكوارتز (١٠% من وزن الرمل) بودرة الحديد (١٠% من وزن الرمل) الألياف الصلب نوع وجرعة الاضافة(٠.٥ الى ٢% من وزن المواد الناعمة) على مقاومة الضغط لهذا النوع من الخرسانة. وتم التوصل إمكانية إنتاج خرسانة فائقة المقاومة بإستخدام المواد المحلية المتوافرة فى السوق المصرية. و يعتمد إنتاج هذا النوع من المونة فائقة المقاومة على الاختيار الأمثل للمواد ومقاساتها ومحتوياتها ونسبتها فى الخلطة وقد اعتمدت تكنولوجيا انتاج هذه النوعية من المونة على تقليل الفراغات إلى أقل نسبة ممكنة فكان محتوى الاسمنت يعادل ٨٧٥ كجم/م٣ ونسبة الماء للمواد الناعمة ٣٠% وعندجرعة اضافة ٠.٥ % وباستخدم ١٠ % غبار سليكا. وتم التوصل الى مقاومة ضغط حوالى ١٢٧ ميجا باسكال ومع استخدام الألياف الصلب بمحتوى ٤٠ كجم/م٣ زادت مقاومة الضغط حتى ١٣٥ كجم/م٣.

Keywords: Quartz; Dolomite; Silica fume; Steel powder; Superplasticizers; Ultra high strength; Steel fibers

1. INTRODUCTION

Ultra-high performance concrete (UHPC) is a new class of concrete that has been developed in recent decades. First research carried out on UHPC where led by Bouygues from 1990 to 1995 on Reactive Powder Concretes (RPC) [1-5]. UHSC is composed of cement, fine sand, quartz powder, micro silica, steel fibers and HRWRA. The addition of micro silica enhances the mechanical properties of the paste by filling voids, enhancing reheology, and producing secondary hydrates. Dili and Santhanam, [4] reported that the quartz powder is useful for its reactivity during heat treatment. Although there are differences among the types of UHPC, there are also many overall similarities. UHPC tends to have the following properties: compressive strength; the use of reinforcement fibers to avoid brittle behavior, high binder content with special aggregates, stiffness and durability [6]. Richard and Cheyrezy, [7] reported that the compressive strength greater than 200 Mpa was achieved. One of the materials developed in recent years is UHSC also known as reactive powder concrete (RPC). This material possesses a compressive strength greater than 150 MPa. According to Vivekanandam and Patnaikuni, [8] HPC with small aggregates is similar to a strong rock. In the mid 1980s, HPC with compressive strength up to 110 Mpa was considered for precast and prestressed structural members. In a recent works by Sobolev [9] it has been demonstrated that a compressive strength up to 145 MPa could be attained but by using the so-called high performance cement and eliminating the coarse aggregate. UHPC tends to have very low water content and can achieve sufficient rheological properties through a combination of optimized granular packing and the addition of high-range water-reducing admixtures [10]. The reduction of the water-cement ratio results in a decrease in porosity and refinement of capillary pores in the matrix. In high performance concrete water to cement ratio ranges usually between 0.28 and 0.38. In ultra-high performance concrete the water to cement ratio can even be lower than 0.2 [12]. An attempt has been made to develop UHSC mixtures with locally available materials by Allena and Newtson [12]. The greatest compressive strengths obtained were 165.6 MPa for UHSC with steel fibers and 161.9 MPa for UHSC without fibers [12]. Although high-strength concrete is often considered a relatively new material, its development has been gradual over many years [13-15]. The possibility of achieving high strength, durability, and improved ductility with the use of ultra high strength concrete encourages researchers and engineers to use this modern material in many practical applications like nuclear waste containment structures, high rise structures, long span bridges, and walkways. Nemours researches have reported that the ultra high strength concrete has remarkable flexural strength and very high ductility compared with conventional concrete [16-19]. The low permeability and the high durability of UHSC lead to wide range of applications [20]. Flexure members in reinforced concrete structures are designed to fail in a ductile manner. So, upper limits in design codes set the amount of longitudinal reinforcement to ensure yielding of steel before concrete reaches crushing strains. Different design codes predicted the shear strength and flexural strengths for UHS reinforced concrete beams, [21-24]. Common shear failure patterns are shear-tension, shear compression, diagonal tension and arch-rib failures. The details of different failure modes are illustrated in ACI-ASCE [25]. Charron et al [26] studied the permeability of Ultra High Performance Fiber Reinforced Concrete (UHPFRC). Where UHPFRC present outstanding mechanical properties and a very low permeability, which make them very attractive for the rehabilitation of existing structures and for new conceptions. UHPFRC are characterized by a significant tensile strain hardening that can be used to optimize the mechanical performance of composite structural elements. Dario Redaelli and Aurelio Muttoni [27] constructed a numerical model to study the tensile behavior of reinforced ultra-high performance fiber reinforced concrete elements. UHPFRC has a very high compressive strength (in the order of 200 MPa) and a relatively large tensile strength (in the order of 10 MPa), along with a strain hardening behavior in tension that ensures that crack openings remain small and provides an enhanced material ductility compared to ordinary concrete[27]. The world's first engineering structure designed with UHPC was the Sherbrooke footbridge in Sherbrooke, Quebec, built in 1997 [28]. The concrete had a compressive strength of 150 MPa and contained 2.5% steel micro fibers (by volume). At the end of year 2000, the AFGC-SETRA working group on UHPC visited a cooling tower at the Cattenom power plant. It was the opportunity to compare UHPC condition with steel elements. Under a normal layer of sediment, no damage of UHPC was noticed. During years 2000-2001, the French Government, represented by its Regional Department of Public Works for the Drôme district with the assistance of the Service d'Etudes Techniques des Routes et Autoroutes (SETRA) and the Centre d'Etudes Techniques de l'Equipement (CETE) of Lyon, realized the world first UHPC bridges, built by contractor Eiffage Construction with BSI on Valence by-pass [29-31]. The road deck was made continuous by placing in situ UHPC between the two spans. In 2001-2002, contractor Bouygues TP built a footbridge over the Han River running across Seoul in South Korea. Jointly conceived by the City of Seoul and "France's Year 2000 Committee" to commemorate the new Millennium, the footbridge symbolizes the cooperation and friendship between South Korea and France.

2. Experimental Program

To achieve the aims of the study of this research, Fourth-nine different concrete mixes were prepared and tested. Table (1) illustrates the details of the concrete mixes. The content of cement ranged from (678-919 kg/m^3). Silica fume was used in all mixes with three percentages (10%, 15% and 20%) as a replacement of cement content. Water-powder ratios ranged from (0.2 – 0.45) for the mixes with silica fume only and without superplacitizers. On the other hand, for the mixes containing silica fume and superplacitizer, the water-powder ratios ranged from (0.22 - 0.3) and the superplacitizers powder ratios ranged from (0.5% - 2%). Different dolomite-sand ratios were used; 1.4, 1.6 and 1.8. Quartz and steel powder were used with 10 % of sand content. Steel fibers raged from (40 & 80 kg/m^3).Water curing until the testing specimens was considered.

2.1 Materials

Locally produced Portland cement (CEMI: 52.5 N) conforming to the requirements of E.S.S. 4756-1/2007 with specific gravity of 3.16 and Blain fineness of 4850 cm^2/gm was used. Locally produced densified silica fume (SF) was delivered in 15-kg sacks. According to the manufacturer, the powder had a specific gravity of 2.2, specific surface area of 17 m^2/gm. Locally produced quartz powder with Blaine fineness of 3000 cm^2/gm, and a specific gravity of 2.85 was used in some mixes. Natural sand having a fineness modulus of 2.72 and a specific gravity of 2.58 t/m^3 was used. The coarse aggregate used was crushed dolomite with a maximum nominal size of 10 mm was used, with a specific gravity 2.75 and absorption of 2.0 %. Different dolomite-sand ratios were used; 1.4, 1.6 and 1.8. Three different types of superplasticizer of modified polycarboxylates were used (Sikament-NN, SikaViscoCrete®-10 and Rheobuild® 840). These admixtures are classified as high range water reducing concrete admixture. Sikament®-NN is a brown liquid with a specific gravity of 1.2 kg /lit at 20°C. SikaViscoCrete®-10 confirms to ASTM-C-494 Type G and F. SikaViscoCrete®-10 is considered as aqueous solution of modified Polycarboxylate. The admixture is a Turbid liquid with a specific gravity of 1.08 kg /lit at 20°C. Rheobuild® 840 confirms to ASTM-C-494 Type D and G. Rheobuild® 840 is formulated from Synthetic polymers specially designed. The admixture is a dark brown liquid with a specific gravity of 1.2 kg /lit at 20°C. Steel fibers with Aspect ratio 65 were used.

2.2 Casting and mixing procedures

Most of published work in literature was concentrating on the role of a low water-cement ratio to produce ultra high strength concrete. The fine materials (cement, silica fume, quartz powder and steel powder) were thoroughly mixed for two minutes. The sand and dolomite were gradually added to the dry materials. The chemical admixture was added to the whole amount of the mixing water that was then added gradually and mixing continued for seven minutes until getting homogenous mix. For the while forty nine mixes presented in this study, compression tests were carried out to obtain the compressive strength at 3, 7 and 28 days. Three cubes 70 × 70 × 70 mm were tested at each age for the mixes without dolomite, while three cubes 100 × 100 × 100 mm were tested for those containing dolomite.

3. Results and Discussions

The experimental work consisted of two phases; the first phase included casting of 19 concrete mixes, which were carried out to reflect represent the effect of silica fume on the compressive strength of the mixes. The effect of cement content, quartz powder, dolomite, types of superplasticizer, steel powder and steel fibers on the compressive strength of concrete mixes are considered in the second phase. 30 concrete mixes in this phase were cast to achieve the compressive strength for the optimum compressive strength considered in the first phase. The results of the compressive strength at different ages (3, 7 and 28 day) for all mixes were shown in Table (2).

3.1 Effect of water-powder ratios

Water-cement ratio has a main effect on the strength of the mixes. Eighteen mixes were prepared with various water cement ratios (0.20, 0.25, 0.30, 0.35, 0.40 and 0.45). Six mixes of them contained 10 % of silica fume as a replacement of cement content, (mixes 2, 5, 8, 11, 14 and 17). Mixes (3, 6, 9, 12, 15 and18) contained 15% silica fume as a replacement of cement content, while 20 % silica fume as a replacement of cement content was used for the mixes (4, 7, 10, 13, 16 and 19). Figures (1) to (3) illustrated the effect of water-cement ratio on the compressive strength for the similar mixes at different ages.

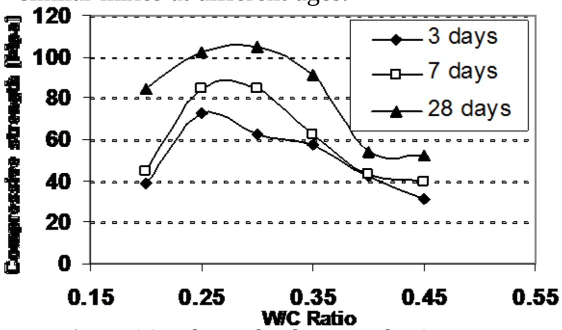

Figure (1) Relationship between the Compressive Strength and Water / Cement Ratio at 10% of silica fume as a Replacement of Cement Content

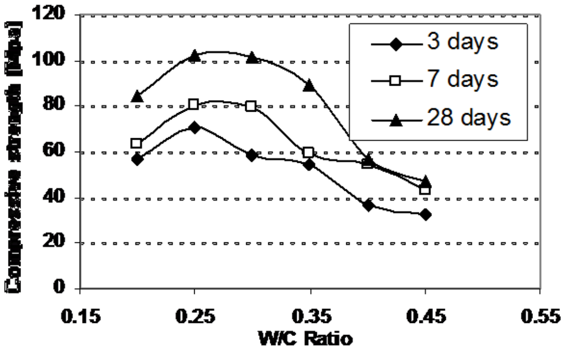

Figure (2) Relationship between the Compressive Strength and Water / Cement Ratio at 15% of Silica fume as a Replacement of Cement Content

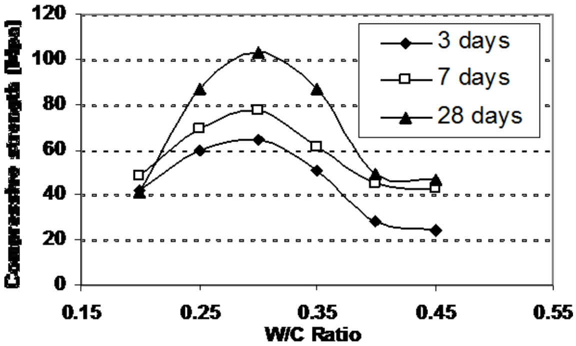

Figure (3) Relationship between the Compressive Strength and Water / Cement Ratio at 20% of Silica Fume as a Replacement of Cement Content

Figure (1) showed a comparison between the compressive strength at ages (3, 7 and 28 day) for mixes 2, 5, 8, 11, 14 and 17 with water-cement ratios 0.2, 0.25, 0.30, 35, 0.4 and 0.45, respectively. The compressive strength of all mixes contain silica fume at 3, 7 and 28 day were greater than those of the control mix (mix 1) without silica fume. After 3 days, the mixes containing water-cement ratio of 0.3 (mix 8) showed the highest compressive strength if compared to the results the mixes with other water-cement ratios 0.2, 0.25, 0.35, 0.4 and 0.45 It seems that with such small ratios of w/c (0.2and0.25), the amount of calcium hydroxide developed through the cement hydration process may not be sufficient to complete the pozzolanic reaction of silica fume. This trend was also noticed at 7 and 28 day. On the other hand, the effect of using silica fume was not significant at early ages. At 3 days; the enhancement in the compressive strength was -38.2%, 16.2%, -8.12%, -33.12% and –50.4% compared to the mix 8, which had 62.8 MPa. At 7 days; the percentages of increasing in the compressive strength were -46.9%, 0 %, 26.4%, -49.2% and -52.8% compared to the mix 8, which had 84.7 MPa. At 28 day; the enhancement in the compressive strength was -19.4%, 2.85%, -12.96%, -48.8 % and -50.52 % at 28 days compared to the mix 8, which had 105.1 MPa. Similar trend was achieved when the concrete mixes included 15% and 20% silica fume as a replacement of cement content at 3, 7 and 28 days as presented in Figures (2) and (3). From the above results, it can be noticed that the maximum compressive strength in this research was 62.8, 84.7 and 105.1 MPa at 3, 7 and 28day respectively. These results were achieved when using 10% silica fume as a replacement of cement content and 874 kg/m^3 cement content at a water-cement ratio 0.3. Other high compressive strength values of 101.6 and 103.1 MPa were achieved when using 15 % and 20% silica fume at 0.3 water-cement ratios.

3.2 Effect of silica fume content

At this section, the optimum content of silica fume will be investigated for mixes without superplasticizer (mixes No (2 to 19). Figure (4) illustrated the effect of using silica fume as a replacement of cement content on the compressive strength of the similar mixes at different ages (3, 7 and 28 day). The mixes (8, 9 and 10) had the water-cement ratio 0.3 and cured in water. In general using silica fume increases the compressive strength at later ages. This led to the pozzolanic reaction of the used silica fume. It can be seen that; the compressive strength of concrete mixes at 3, 7and 28 day increases with decreasing the amount of silica fume in the mixes. The compressive strength enhanced at mixes, which included 10% of silica fume, where the maximum compressive strength is recorded. The amount of improvement in 3 days compressive strength of concrete mixes reaches 54 %, 44 % and 58 %, when using 10%, 15% and 20% silica fume as a replacement of cement content respectively compared to that of control mix (1). The amount of improvement in 7 days compressive strength of concrete mixes reaches 36 %, 27% and 25 %, when using 10%, 15% and 20% silica fume as a replacement of cement content respectively compared to that of control mix (1). While, at the 28 days 35% 30 % and 32% improvement in compressive strength when 10%, 15% and 20% silica fume as a replacement of cement content were used compared to control mix (1). The role of silica fume in increasing the compressive strength seems to be very significant. For the control mix without silica fume (mix 1) showed the lowest strength levels. Accordingly, extra dosage of silica fume may be useless since another filler element already does exist in the matrix, which is unhydrated cement particles. On the other hand, it is observed during mixing that the presence of silica fume improves the workability of concrete mixes. All mixes with silica fume, showed a relatively higher workability and easier casting ability when compared to control mix. (1) The measured slump for the mixes was 60 ± 5 mm.

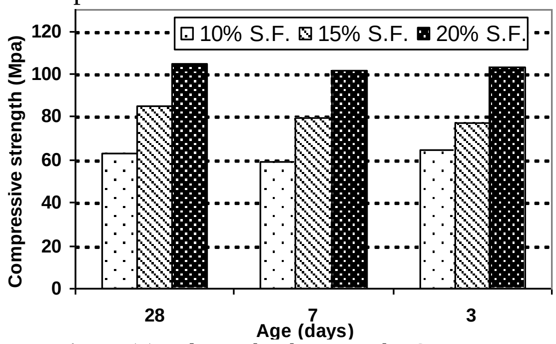

Figure (4) Relationship between the Compressive Strength of Different Percentages of Silica Fume as a Replacement of Cement Content at 0.3 W/C Ratios.

The compressive strength values of the mixes (1 to 19) are presented in Figure (5). The maximum compressive strength was recorded for mix (8) as shown in the Fig.(5).The compressive strength values 62.8, 84.7 and 105.1 Mpa at 3, 7 and 28 days respectively.

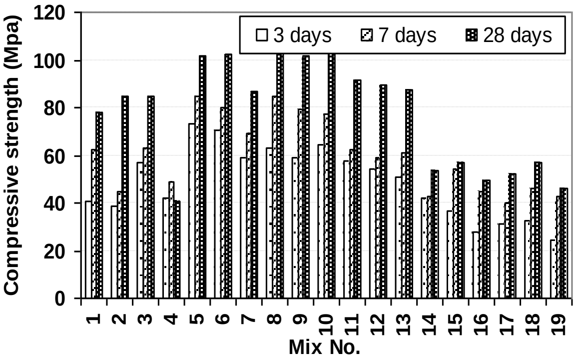

Figure (5) Relationship between the Mix No. and the Compressive Strength for the Mixes Contain different Percentages of Silica Fume Mixes without Superplasticizer

4.3 Effect of types and dosage of superplacitizers

Three different types of superplasticizer were used. The trade names of these admixtures are Sikament-NN, SikaViscoCrete® -10 and Rheobuild® 840. These admixtures are classified as high range water reducing concrete admixture. 0.5 to 2 % of superplacitizers were used by weight of powder (cement and filler). Table (2) showed the effect of different percentage of Rheobulid@840 on the compressive strength (mixes 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31 and 32). The results of mixes showed improving in compressive strength at 0.5% superplasticizers at 0.3 Water-powder ratio as shown in mix (30). At this Point different superplasticizers were used to investigate the effect of these types of superplasticizers available in local Egyptian market on the compressive strength. Figures (6) illustrated the effect of different types of superplasticizers on the compressive strength at dosage 0.5% and 0.3 water-powder ratio. This figure illustrated that the compressive strength for the mixes contains SikaViscoCrete®-10 had the highest 7 days compressive strength while the highest compressive strength of concrete mix was for the Sikament-NN (mix 36) at 28 day. Mix (36) had 127 Mpa at 28 days this value was increased by 20.8% compared to mix (8), which had 105.1 Mpa compressive strength

3.4 Effect of using aggregate

Dolomite was used in six mixes contained dolomite as a coarse aggregate (mixes 39, 40, 41, 42, 43 and 44). Different dolomite-sand ratios were used in these mixes 1.4, 1.6 and 1.8. While consist of 10 and 20 % quartz powder as a replacement of sand content were used (mixes 45 and 46). Mix 47 contained 10% steel powder as a replacement of sand content. 10% silica fume as a replacement of cement content was used in these mixes.

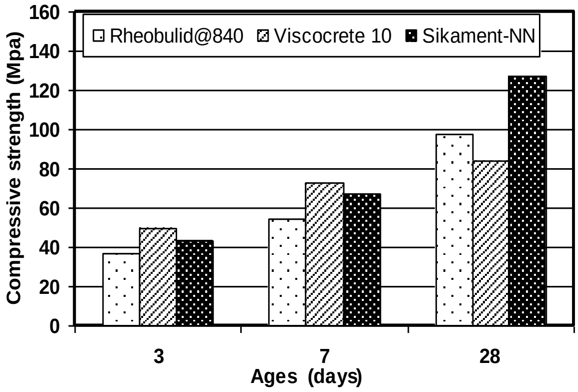

Figure (6) Effect type of superplasticizers on the compressive strength at Water-Cement ratio 0.3

Figure (7) and (10) showed the effect of using aggregate types on the compressive strength at different ages. These mixes (39, 40, 41, 42, 43, 44, 45, 46 and 47) were compared to the mix (8) and mix (36), which had a compressive strength 105.1and 127 MPa at 28 days respectively. Figures (7) and (8) illustrated the effect of dolomite-sand ratios on the compressive strength. It can be observed that mixes contain 1.4 dolomite-sand ratios showed higher compressive strength for the mixes without superplasticitizers as illustrated in Figure (7). While when using superplasticitizers the compressive strength was increased with increasing the dolomite-sand ratios. In addition the compressive strength for the mixes contains dolomite showed a compressive strength lower than mix (8) and mix (36) either with superplacitizer or without superplacitizers. The reduction in the compressive strength for the concrete mixes led to the strength of the mortar is usually more than that of coarse aggregate. In addition using quartz powder as replacement of sand content increased the compressive strength compared to the mixes contains the dolomite. This could be attributed to the filling ability of the fine quartz materials. Also the mixes contained quartz powder showed lower compressive strength than the compressive strength for mix (8) and mix (36) as illustrated in Figure (9). The same trend was observed in Figure (10) when using steel powder. Figure (11) show compassion between the different types of aggregate.

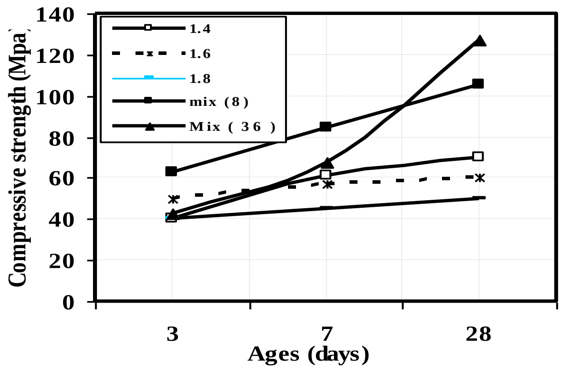

Figure (7) Effect of Dolomite-Sand ratios on the Compressive Strength without Superplasticizers

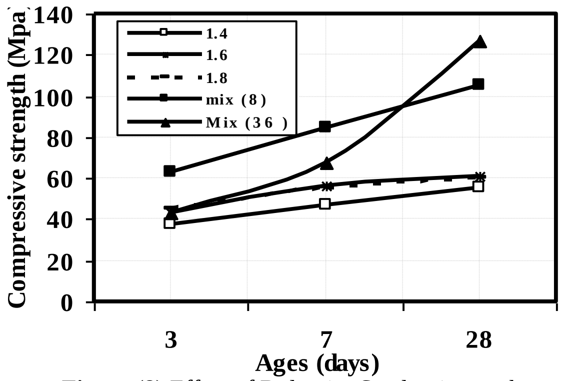

Figure (8) Effect of Dolomite-Sand ratios on the Compressive Strength using 0.5 % Superplasticizers

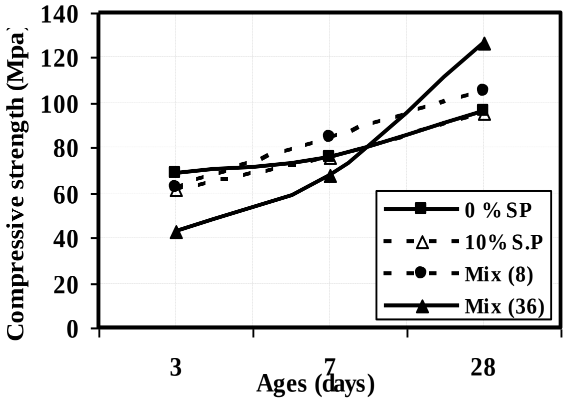

Figure (9) Effect of Quartz Powder on the Compressive Strength.

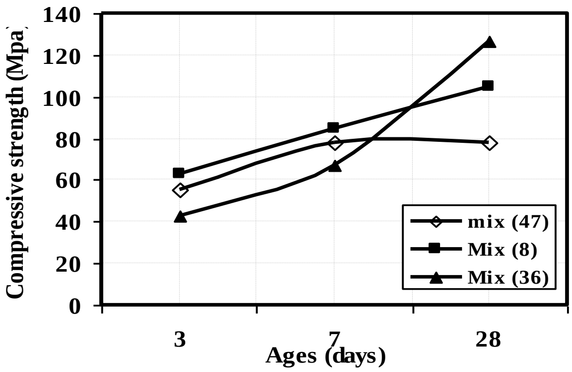

Figure (10) Effect of Steel Powder on the Compressive Strength

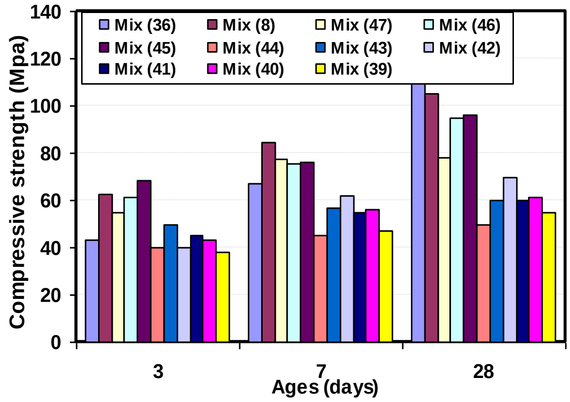

Figure (11) Comparison between the Compressive Strength and the Ages for the Concrete Mixes Contained different Types of Aggregates

3.5 Effect of fibers:

Steel fibers were added to achieve the compressive strength of the mixes by 40 and 80 kh/m^3 (mixes 48 and 49). Figure (12) illustrated, at 28 day, the compressive strength increases to 135 and 130 Mpa for mix 48 and mix 49 respectively compared to the mix 36. The compressive strength increases by 49.5, 36.8 and 6.3 %) at 3, 7, and 28 day for mix (48) compared by the mix (36). The compressive strength increases by (54.7, 29 and 2.4% for mix (49) compared by the mix (36).

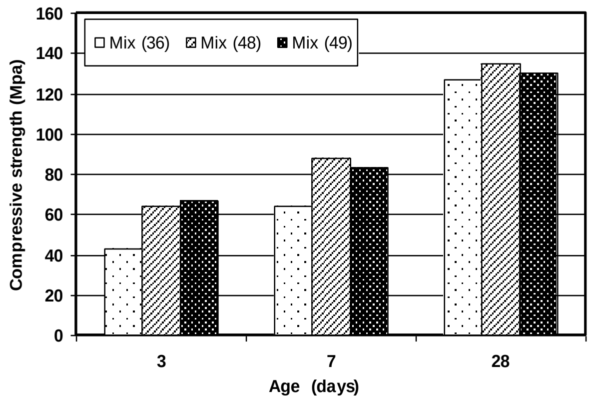

Figure (12) Effect of Steel Fibers on the Compressive Strength

4. CONCLUSIONS

From the results of this research, the following conclusions could be drawn as follows:

1. The possibility of producing ultra high strength concrete using local materials available in the Egyptian market.
2. The technology to produce this type of concrete is based on eliminating the coarse aggregates and using coarse fine aggregate.
3. Using 10% silica fume as a replacement of cement content can produce ultra high strength.
4. Using 10% silica fume as a replacement of cement content and 0.3 water cement ratio

without any superplasticizer resulted in compressive strength after 3, 7 and 28 days of 62.8, 84.7 and 105.1 MPa, respectively.

5. Using dolomite as a coarse aggregate resulted in a reduction in the compressive strength because the strength of the mortar is usually more than that of concrete.
6. 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.
7. 0.5 % of the superplasticizer by weight of powder, 0.3 water cement ratio and 10 % silica fume as a replacement of cement content were achieved the highest compressive strength, especially at early ages.
8. the highest compressive strength of 127 Mpa was achieved by a mix incorporating 10 % silica fume, water cement ratio of 0.3 and superplasticizer by trade name Sikament-NN of dosage 0.5 %
9. The compressive strength was increased to (64.3, 88.0 and 135 MPa) after 3, 7 and 28 days when using 40 kg/m^3 steel fibers.

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Table 1 Concrete mix proportion for trial mixes without superplasticizers

<table>
<tr><th rowspan="2">Mix No</th><th colspan="4">Materials Required For One Cubic Meter (Kg/m³)</th></tr>
<tr><th>Cement</th><th>Sand</th><th>Water</th><th>Silica fume</th></tr>
<tr><td>1</td><td>885</td><td>974</td><td>354</td><td>-</td></tr>
<tr><td>2</td><td>969</td><td>1132</td><td>215.20</td><td>215.2</td></tr>
<tr><td>3</td><td>915</td><td>1106</td><td>215.20</td><td>215.2</td></tr>
<tr><td>4</td><td>861</td><td>1080</td><td>215.20</td><td>215.2</td></tr>
<tr><td>5</td><td>919</td><td>1074</td><td>255.25</td><td>255.25</td></tr>
<tr><td>6</td><td>868</td><td>1049</td><td>255.25</td><td>255.25</td></tr>
<tr><td>7</td><td>817</td><td>1025</td><td>255.25</td><td>255.25</td></tr>
<tr><td>8</td><td>874</td><td>1023</td><td>291.30</td><td>291.3</td></tr>
<tr><td>9</td><td>825</td><td>999</td><td>291.30</td><td>291.3</td></tr>
<tr><td>10</td><td>777</td><td>976</td><td>291.30</td><td>291.3</td></tr>
<tr><td>11</td><td>833</td><td>975</td><td>324.10</td><td>324.1</td></tr>
<tr><td>12</td><td>787</td><td>953</td><td>324.10</td><td>324.1</td></tr>
<tr><td>13</td><td>741</td><td>931</td><td>324.10</td><td>324.1</td></tr>
<tr><td>14</td><td>797</td><td>932</td><td>354.00</td><td>354</td></tr>
<tr><td>15</td><td>752</td><td>911</td><td>354.00</td><td>354</td></tr>
<tr><td>16</td><td>708</td><td>890</td><td>354.00</td><td>354</td></tr>
<tr><td>17</td><td>763</td><td>892</td><td>381.60</td><td>381.6</td></tr>
<tr><td>18</td><td>721</td><td>872</td><td>381.60</td><td>381.6</td></tr>
<tr><td>19</td><td>678</td><td>851</td><td>381.60</td><td>381.6</td></tr>
</table>

Table 2 Concrete mix proportion for mixes with superplasticizers

<table>
<tr><th rowspan="2">Mix No</th><th colspan="11">Materials Required For One Cubic Meter (Kg/m³)</th></tr>
<tr><th>Cement</th><th>Sand</th><th>W</th><th>Dolomite</th><th>Quartz</th><th>S.F</th><th>S.P.1</th><th>S.P.2</th><th>S.P.3</th><th>Steel Powder</th><th>Steel fibres</th></tr>
<tr><td>20</td><td>919</td><td>1062</td><td>255.25</td><td rowspan="10">-</td><td rowspan="10">-</td><td>102</td><td>5.10</td><td rowspan="10">-</td><td rowspan="10">-</td><td rowspan="10">-</td><td rowspan="10">-</td></tr>
<tr><td>21</td><td>919</td><td>1051</td><td>255.25</td><td>102</td><td>10.21</td></tr>
<tr><td>22</td><td>919</td><td>1039</td><td>255.25</td><td>102</td><td>15.30</td></tr>
<tr><td>23</td><td>777</td><td>1004</td><td>276.70</td><td>194</td><td>4.86</td></tr>
<tr><td>24</td><td>777</td><td>1032</td><td>262.20</td><td>194</td><td>9.71</td></tr>
<tr><td>25</td><td>777</td><td>1060</td><td>247.60</td><td>194</td><td>14.57</td></tr>
<tr><td>26</td><td>777</td><td>1088</td><td>233.00</td><td>194</td><td>19.42</td></tr>
<tr><td>27</td><td>777</td><td>965</td><td>291.30</td><td>194</td><td>4.86</td></tr>
<tr><td>28</td><td>777</td><td>954</td><td>291.30</td><td>194</td><td>9.71</td></tr>
<tr><td>29</td><td>777</td><td>932</td><td>291.30</td><td>194</td><td>19.42</td></tr>
<tr><td>30</td><td>777</td><td>965</td><td>291.30</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">194</td><td>4.86</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">-</td></tr>
<tr><td>31</td><td>777</td><td>954</td><td>291.30</td><td>9.71</td></tr>
<tr><td>32</td><td>777</td><td>932</td><td>291.30</td><td>19.42</td></tr>
<tr><td>33</td><td>874</td><td>1012</td><td>291.30</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">97</td><td rowspan="3">-</td><td>4.86</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">-</td></tr>
<tr><td>34</td><td>874</td><td>1141</td><td>242.80</td><td>9.71</td></tr>
<tr><td>35</td><td>874</td><td>1230</td><td>213.60</td><td>19.42</td></tr>
<tr><td>36</td><td>874</td><td>1012</td><td>291.30</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">97</td><td rowspan="3">-</td><td rowspan="3">-</td><td>4.86</td><td rowspan="3">-</td><td rowspan="3">-</td></tr>
<tr><td>37</td><td>874</td><td>1141</td><td>242.80</td><td>9.71</td></tr>
<tr><td>38</td><td>874</td><td>1230</td><td>213.60</td><td>19.42</td></tr>
<tr><td>39</td><td>874</td><td>380</td><td>306.00</td><td>615</td><td rowspan="6">-</td><td rowspan="6">97</td><td rowspan="6">-</td><td rowspan="6">-</td><td>14.57</td><td rowspan="6">-</td><td rowspan="6">-</td></tr>
<tr><td>40</td><td>874</td><td>399</td><td>306.00</td><td>560</td><td>14.57</td></tr>
<tr><td>41</td><td>874</td><td>368</td><td>305.90</td><td>389</td><td>14.57</td></tr>
<tr><td>42</td><td>874</td><td>426</td><td>277.30</td><td>597</td><td>19.42</td></tr>
<tr><td>43</td><td>874</td><td>410</td><td>262.17</td><td>656</td><td>19.42</td></tr>
<tr><td>44</td><td>874</td><td>365</td><td>278.20</td><td>657</td><td>19.42</td></tr>
<tr><td>45</td><td>874</td><td>928</td><td>291.30</td><td rowspan="2">-</td><td rowspan="2">102</td><td rowspan="2">97</td><td rowspan="2">-</td><td rowspan="2">-</td><td>-</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>46</td><td>874</td><td>928</td><td>291.30</td><td>10.73</td></tr>
<tr><td>47</td><td>874</td><td>989</td><td>291.30</td><td>-</td><td>-</td><td>97</td><td>-</td><td>-</td><td>-</td><td>99.0</td><td>-</td></tr>
<tr><td>48</td><td>874</td><td>1012</td><td>291.30</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">97</td><td rowspan="2">-</td><td rowspan="2">-</td><td>4.86</td><td rowspan="2">-</td><td>40</td></tr>
<tr><td>49</td><td>874</td><td>1012</td><td>291.30</td><td>4.86</td><td>80</td></tr>
<tr><td colspan="12">W: water SF: Silica fume Sp1: Rheobulid@840 Sp2:Sika ViscCrete 10 Sp3:Sikament-NN</td></tr>
</table>

Table 3 Compressive strength of the Different concrete mixes

Mix No	Compressive strength (Mpa)			Mix No	Compressive strength (Mpa)			Mix No	Compressive strength (Mpa)		
	3 days	7 days	28 days		3 days	7 days	28 days		3 days	7 days	28 days
1	40.8	62.2	78.1	18	32.7	46.0	57.1	35	60.2	88.8	91.9
2	38.8	44.9	84.7	19	24.5	43.0	46.3	**36**	**43.0**	**67.4**	**127.0**
	57.0	63.3	84.7	20	60.2	84.2	91.8	37	64.3	88.0	89.0
4	42.0	48.5	40.8	21	41.9	79.6	81.6	38	66.5	83.0	87.0
5	73.0	84.7	102.0	22	49.0	71.4	67.3	39	40.0	61.5	70.0
6	70.5	80.0	102.1	23	50.0	73.5	79.6	40	50.0	57.0	60.0
7	59.2	68.9	86.8	24	59.2	72.5	75.0	41	40.0	45.0	50.0
8	**62.8**	**84.7**	**105.1**	25	55.1	64.3	76.6	42	38.0	47.0	55.0
9	58.7	79.6	101.6	26	50.5	62.3	74.5	43	43.0	56.0	61.5
10	64.3	77.6	103.1	27	40.8	49.0	77.6	44	45.0	55.0	60.0
11	57.7	62.3	91.4	28	44.9	45.0	81.6	45	68.4	76.0	96.0
12	54.1	59.2	89.3	29	40.8	36.8	63.3	46	61.3	75.5	97.5
13	51.0	61.3	87.3	**30**	**36.7**	**54.1**	**98.0**	47	55.1	77.6	78.0
14	42.0	43.0	53.8	31	30.6	48.0	79.6	**48**	**64.3**	**88.0**	**135**
15	36.7	54.1	57.1	32	25.6	50.0	95.9	49	66.5	83.0	130
16	28.1	44.9	49.2	33	49.5	73.0	83.7				
17	31.1	40.0	52.0	34	61.8	67.4	72.5				