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*Research Paper*

# THE INFLUENCE OF SIZE OF LIGHTWEIGHT AGGREGATE ON THE MECHANICAL PROPERTIES OF SELF-COMPACTING CONCRETE WITH AND WITHOUT STEEL FIBER

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An experimental work was carried out to produce six mixes Self Compact Concrete with weight ratio [fine/coarse] aggregate ≈1.0, three with steel fiber, and the other without. This research study the effect of using lightweight aggregate in concrete as an alternative to normal weight aggregate, depends on the basis of volumetric fractions (Porcelinite coarse aggregate replacing the natural river gravel as a Mix2 ) and (Porcelinite fine aggregate replacing the sand as a Mix3) on the mechanical properties (Compressive Strength, Splitting Tensile Strength and Unit weight (density)). In addition the effect of these replacements on mechanical properties of concrete with steel fiber-volume fraction (Vf)=0.8% (MixF2 and MixF3) was studied. It is generally found that Mix2 and Mix3 lead to a decrease in compression, tensile strength and Unit weight (density) in comparison to reference Mix (Mix1, normal weight aggregate), However the percentage of decreasing of Mix2 on compression, tensile strength was found to be higher than the percentage of decreasing of Mix3. On the other hand this work studied the effect of adding steel fiber - volume fraction (Vf) on mechanical properties of two mixes groups [mix1, mix2 and mix3] and [mixF1, mixF2 and mixF3] having steel fiber -volume fraction of 0.0%, 0.8%, respectively and found that the tensile strength was increased significantly with adding steel fiber while the compressive strength and unit weight (density) was slightly increased.

***Keywords:*** Lightweightconcrete, Porcelinite, Self compact concrete, Steel fiber, Mechanical properties

## INTRODUCTION

The advantages of light weight concrete over normal weight concrete are numerous and well known e.g. lower density, higher strength/ weight ratio (Al-Khaiat and Haque, 1998), lower coefficient of thermal conductivity (Al-Jabri *et al.,* 2005, Uysal, 2004), better fire resistance (Bilodeau *et al.,* 2004), improved durability properties (Hwang *et al.,* 2005, Gao *et al.,* 1997) and etc. Reduced dead load obtained by use of lightweight concrete not only result in a decrease in cross section of

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columns, beams, walls and foundations, but also decrease the induced seismic loads and reduce the risk of earthquake damages to structures (Topcu, 1997) since, the earthquake loads influencing the structures and buildings are proportional to the mass of those structures and buildings. Structural Light Weight Aggregate Concrete (LWAC) are usually produced by replacing a whole or a part of natural normal weight aggregate by artificial or natural Light Weight Aggregate (LWA). The weakness of LWA contributes on reduced tensile and flexural strength of LWAC. Brittleness of LWAC is on the contrary with the main objective of LWAC that requires ductile behavior in seismic loads. This disadvantage can be overcome by utilizing appropriate amount of fibers (Tomosawa, 1996, Mirza and Soroushian, 2002, Soroushian, 1992). The use of fibers to reinforce a brittle material can be traced back to Egyptian times when asbestos fiber was used to reinforce clay pots about 5000 years ago (Mehta, 2006). However, the modern development of fiber reinforced concrete in the concrete industry may have begun around the early 1960s (Li, 2002). The most beneficial characteristics of fiber-reinforced systems are those of increased flexural capacity, toughness, post-failure ductility and crack control (Edgington *et al.,* 1974). In addition, it has been reported (Ding, 2000) that fiber reinforcement in concrete significantly increases the compressive ductility, toughness and energy absorption at early ages. In this research using Self-Compacting Concrete (SCC), as the name indicates, a type of concrete that does not require external or internal compaction, because it becomes leveled and compacted under its self-weight. SCC can spread and fill every corner of the formwork purely by means of its self-weight, thus eliminating the need of vibration or any type of compacting effort (Okamura, 1998).

## EXPERIMENTAL WORK

### Materials

#### *Cement*

Ordinary Portland local cement from Tasluja factory was used in all mixes throughout this research.

#### *Normal Fine Aggregate*

The fine aggregate (sand), which has been selected for present work, was obtained from Al-Ukhaidher area. The fine aggregate has 4.75 mm maximum size with rounded particle shape and Specific gravity (2.6). The physical and chemical tests of the fine aggregate were carried out by the National Center for Construction Laboratories and Research. The obtained results indicate that the fine aggregate grading and the sulfate content were within the Iraqi specification No. 45/1984. Table 1 shows the grading of fine aggregate and the limits specified. In all concrete batches the sand was dried in air before being used.

#### *Normal Coarse Aggregate*

Normal weight, crushed aggregate of maximum size 10 mm with Specific gravity (2.63) was used. It was brought from AL-Nabai region. The physical and chemical tests of coarse aggregate were carried out by the National Center for Construction Laboratories and Research. Table 2 show the grading of

| Table 1: Grading of Fine Aggregate | | | |
|---|---|---|---|
| S. No. | Sieve Size mm | % Passing | |
| | | %Coarse Aggregate | ASTM C33 Limits |
| 1 | 12.5 | 100 | 100 |
| 2 | 9.5 | 94 | 85-100 |
| 3 | 4.75 | 23 | 10-30 |
| 4 | 2.36 | 2.5 | 0-10 |
| 5 | 1.18 | 1.0 | 0-5 |

| Table 2: Grading of Coarse Aggregate | | | |
|---|---|---|---|
| S. No. | Sieve Size mm | % Passing | |
| | | Fine Aggregate % | Iraqi specification No. 45/1984 for Zone(3) |
| 1 | 4.75 mm | 93 | 90-100 |
| 2 | 2.36 mm | 85 | 75-100 |
| 3 | 1.18 mm | 75 | 55-90 |
| 4 | 600 µm | 58 | 35-59 |
| 5 | 300 µm | 29 | 8-30 |
| 6 | 150 µm | 4 | 0-10 |

coarse aggregate and the limits specified by ASTM C33. The grading of coarse aggregate was within this specification, and it has been found that the sulfate content was within the Iraqi specification No. 45/1984.

### *Admixtures (Superplasticizer)*

In this work, a "Sika ViscoCete-PC 20" was used as a superplasticizer with dosage of 3.5 L per 100 kg of cement, this dosage was recommended after many trail mixes. This admixture improves the mix in:

- Extremely powerful water reduction, resulting in high density , high strength and reduced permeability for water.
- Excellent plasticizing effect ,resulting in improved flowability, placing and compacting behavior.
- Especially suitable for the production of Self Compacting Concrete (SCC)

Properties of the superplasticizer are presented in Table 3.

**Table 3: Properties of the Superplasticizer***

| No. | Property | The Description |
|---|---|---|
| 1 | Commercial name | Sika ViscoCete-PC 20 |
| 2 | Chemical Base | Modified polycaboxylates based polymer |
| 3 | Form | Liquid |
| 4 | Color | Light brown |
| 5 | Relative density | 1.09-1.13 kg/l @ 20° C |
| 6 | pH | 3 - 7 |
| 7 | Chlorides | Free from chlorides |

**Note:** *Supplied by the manufacturer.

## Steel Fibers

Hooked end steel fibers which are known commercially as Dramix-Type ZC, was used in this work. These fibers were 50 mm long and 0.5 mm diameter (aspect ratio, l/d =100).

Properties of steel fibers are presented in Table 4.

## Mixing Water

Ordinary potable water was used for mixing and curing all concrete mixes in this study

## Porcelinite

Local naturally occurred Lightweight Aggregates (LWA) of porcelinite stone is used as fine and coarse aggregate throughout the tests of light weight concrete. The required quantity of porcelinite stone is brought and tested with the help of the State Company of Geological Survey and Mining. The quarry of this stone is located in Trefawi area (Rutba) at the western desert in Anbar governorate. The Porcelinite lumps are firstly crushed into smaller size manually by means of a hammer in order to facilitate the insertion of the lumps through the feed opening of the crusher machine. The Jaw crusher was setup to give a finished product of about 10 mm maximum aggregate size. In this work, the coarse aggregate was obtained from mixing three sizes shown in Table 9 which conform the requirements of the of ASTM C330-87.

**Table 4: Properties of Steel Fibers***

| Commercial name | Configuration | Property | Specifications |
|---|---|---|---|
| Dramix ZC 50/0.5 |  Cell of Hooked ends | Density | 7860 kg/m3 |
| | | Ultimate strength | 1130 MPa |
| | | Modulus of Elasticity | 200x103 MPa |
| | | Strain at proportion limit | 5650 x10-6 |
| | | Poisson's ratio | 0.28 |
| | | Average length | 50 mm |
| | | Nominal diameter | 0.5 mm |
| | | Aspect ratio ($L_f/D_f$) | 100 |

**Note:** *Supplied by the manufacturer.

**Table 5: Mineral Analysis of Porcelinite Aggregate***

| Compounds | % by weight |
|---|---|
| Opal- CT | 65 |
| Quartz | 10.4 |
| Calacite | 6.25 |
| Dolomite | 7.15 |
| Gypsum | 0.6 |
| Halite | 0.65 |
| Apatite | 1.85 |
| Clay | 7.72 |

**Note:** * Mineral analysis is made by the State Company of Geological Survey and Mining

**Table 6: Chemical Analysis of Porcelinite Aggregate***

| Oxides | % by Weight |
|---|---|
| $SiO_2$ | 74.7 |
| CaO | 12.04 |
| MgO | 0.56 |
| $SO_3$ | 0.3 |
| $Fe_2O_3$ | 0.39 |
| $Al_2O_3$ | 0.63 |
| $TiO_2$ | 0.05 |
| CL | 0.07 |
| Loss on Ignition | 5 |

**Note:** * Physical and chemical analysis are made by the State Company of Geological.

Table 5 shows the mineral analysis of porcelinite aggregate. Physical and chemical properties are determined for porcelinite aggregate. Tables 6 and 7 list these properties. The grading of porcelinite fine aggregate is presented in Table 8 and it lies within the limits of ASTM C330-87.

Porcelinite stone has a white color and is characterized by high permeability, low density and high silicon oxide ($SiO_2$) content. Mainly, this type of stone originates from opal, carbonate, and clay minerals (Bassam, 1986).

Lightweight aggregates absorb more water than normal weight aggregate due to their cellular structure. In order to avoid the continuous absorption of lightweight Porcelinite aggregate which cause rapid slump loss, the aggregate was washed with water in order to remove the dust associated with crushing process of Porcelinite stone. This is because high proportion of dust tends to

**Table 7: Physical Properties of Fine and Coarse Porcelinite Aggregate**

| Properties | Specification | Test Results | |
|---|---|---|---|
| | | Fine | Coarse |
| Specific gravity | ASTM C 127-88[22]ASTM C 128-88[23] | 1.646 | 1.53 |
| Dry loose-unit weightkg/m³ | ASTM C 29-89[24] | 790 | 635 |
| Dry rodded-unit weight kg/m³ | ASTM C 29-89[24] | 830 | 680 |
| Absorption% | ASTM C 127-88[22] ASTM C 128-88[23] | 35.6 | 33.9 |

**Table 8: Grading of Fine Porcelinite Aggregate**

| Sieve Size(mm) | Cumulative Passing% | Cumulative Passing %ASTM C 330 |
|---|---|---|
| 9.5 | 100 | 100 |
| 4.75 | 94.8 | 85-100 |
| 2.36 | 69.8 | - |
| 1.18 | 41.5 | 40-80 |
| 0.30 | 12.8 | 10-35 |
| 0.15 | 5.9 | 5-25 |

**Table 9: Grading of Coarse Porcelinite Aggregate**

| Size of Porcelinite Aggregate(mm) | Using % | Sieve Size(mm) | Cumulative Passing% | Cumulative Passing %ASTM C 330 |
|---|---|---|---|---|
| 12.5< >9.5 | 15 | 12.5 | 100 | 100 |
| 9.5< >4.75 | 55 | 9.5 | 85 | 80-100 |
| 4.75< | 30 | 4.75 | 30 | 5-40 |

segregate and cause crazing of exposed concrete (Taylor, 1977). The Porcelinite aggregate was dripped off and spread away from sun light for a suitable time to bring the aggregate particles to Saturated Surface Dry (SSD) condition, after that breakage in the Nylon bags and these bags store in the Plastic container which is recommended by ACI committee 211-2-81.

### *Limestone Powder (LSP)*

This material is locally named as "Al-Gubra". It is a white grinding material from lime-stones excavated from different regions in Iraq, and usually used in the construction processes. In this work, a fine limestone powder, grinded by blowing technique, has been used.

### Concrete Mixes

The characteristics of concrete types were studied, which contain three series of concrete specimens depended on the basis of volumetric fractions of aggregate (lightweight or normal weight), the following mixes were used:

[mix1 and mixF1] containing normal weight fine and coarse aggregate, with and without steel fiber–volume fraction of ($V_f$)= 0.8%.

[mix2 and mixF2] containing normal sand and lightweight coarse aggregate (by replace the normal gravel to lightweight coarse aggregate by volumetric) with and without steel fiber–volume fraction of ($V_f$) = 0.8% and finally

[(mix3 and mixF3) for lightweight fine aggregate and normal coarse aggregate (by replace the fine normal aggregate to lightweight fine aggregate by volumetric) with and without steel fiber–volume fraction of ($V_f$) = 0.8%

## Concrete Mix

In this work, to produce a nonfibrous concrete (lightweight or normal weight) , the following mixing proportion was used: [cement: Limestone Powder: sand: aggregate] was [1:0.1:1.9:2] by weight and the water–cement ratio was 0.44 with superplasticizer of 3.5% by weight of cement as shown in Table 10. This mix was based on several trial mixes in order to obtain the most suitable mix. It was found that the mentioned mixture produces self compact concrete without segregation

In this research, many types of the product mixes were different between them according to the type of sand and coarse aggregate as shown in Table 10. The replacing of the normal weight aggregate (sand or natural river gravel) to lightweight aggregate (Porcelinite fine or coarse aggregate) depends on the basis of volumetric fractions, according to following equation:

$$W_L = \left[\frac{SG_L}{SG_N} \times W_N\right] \Big/ \left[1 + \frac{A}{100}\right] \qquad ...(1)$$

where Subscript L refers to lightweight aggregate (Porcelinite fine or coarse aggregate)

Subscript N refers to normal weight aggregate (sand or natural river gravel)

W = weight, SG =specific gravity and A=absorption of aggregate

Steel Fiber Reinforced Concrete was obtained by adding steel fibers with volume fractions of 0.8% to the fresh nonfibrous concrete, then remixed. There are two mixture of steel fiber reinforced concrete depending on the volume fraction of steel fiber (0.0% and 0.8%)

This mixing has tended to British practice which has generally relied to high sand content (more than 50% by weight of aggregate) with maximum aggregate size of 10 mm (Hannant, 1978). The workability of the mix and uniform dispersion of the fibers, are important factors that affect the quality of fibrous concrete.

## Mixing Procedure

The mixing procedure is an important factor

**Table 10: Mix Properties By Weight, With Steel Fibers By Volume**

| | Parameter | Cement | Light Weight Aggregate Porcelinite | | Normal Weight Aggregate | | Lime-stone Powder (LSP) | Water/ Cement Ratio | Super-plasticizer (Liter/100kg cement) | Steel Fiber Volume (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fine | Coarse | Fine | Coarse | | | | |
| Concrete Type | Mix1 | 1 | – | – | 1.9 | 2 | 0.1 | 0.4 | 3.5 | – |
| | Mix2 | 1 | – | 2 | 1.9 | – | 0.1 | 0.4 | 3.5 | – |
| | Mix3 | 1 | 1.9 | – | – | 2 | 0.1 | 0.4 | 3.5 | – |
| | Mix F1 | 1 | – | – | 1.9 | 2 | 0.1 | 0.4 | 3.5 | 0.8 |
| | Mix F2 | 1 | – | 2 | 1.9 | – | 0.1 | 0.4 | 3.5 | 0.8 |
| | Mix F3 | 1 | 1.9 | – | – | 2 | 0.1 | 0.4 | 3.5 | 0.8 |

for obtaining the self compact concrete which satisfy criteria of filling ability, passing ability and segregation resistance. The good dispersion of fibers prevents fiber clumping. All batching was done by weight. The concrete was mixed by hand by using a pan. The interior surface of the pan was cleaned and moistened before placing the materials. The fresh concrete was mixed until a homogeneous fresh concrete was obtained. To avoid balling and to distribute the steel fibers uniformly, the required amount of steel fibers was uniformly added to the mix by hand sprinkling. The fresh concrete was then mixed until a good dispersion of the fiber was obtained.

This procedure is briefly stated in the following points:

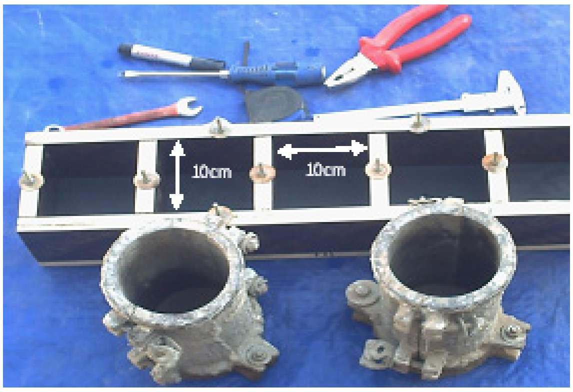
1. Initially the fine, filler and coarse aggregates were poured and mixed for several minutes in the pan and then the cement was added. The materials were mixed until a uniform color was obtained
2. Afterward 50% of the water of 0.4 w/c ratio (which divided the w/c ratio=0.4+0.04) was added to the mix and all components were remixed for a few minutes
3. Then, the (superplasticizer + 20% of the 0.4 w/c ratio were mixed together) and pouring it into the pan and remixing, after that the mixture is left for about five minutes
4. Then, the remaining 30% of the 0.4 w/c ratio was added and mixed until a homogeneous fresh concrete was obtained.
5. Finally the 0.04 of w/c ratio was added and remixed.
6. For the mixes that contain steel fiber. To avoid balling and to distribute the steel fibers uniformly, the required amount of steel fibers was uniformly added to the mix by hand sprinkling. The fresh concrete was then mixed until a good dispersion of the fiber was obtained.

### Casting and Curing

When the mixing process was completed, the control specimens were then cast into the molds as shown in Figure 1, and hammered by rubber driver, at sides and base of the specimens until the casting was completed, the specimens were covered with a plastic sheet to prevent evaporation of water. After (24) hours, the control specimens were stripped from the molds and cured in a water bath for about one month. To keep the temperature about 25º to 30º, two heaters were used which modified for ornamental fish ponds and water pump to distributed the heat in the water bath. Then they were taken out from the water bath, and the control specimens were tested.

The following paragraphs contain the result of the standard tests that were carried out on the fresh concrete, and hardened concrete.

**Figure 1: Details of Wooden Cubic Forms and Cylinders**



# RESULTS AND DISCUSSION

## Testing of Fresh Concrete

### *Slump Flow Test and T50 cm Test*

The slump flow test is used to assess the horizontal free flow of self-compacting concrete. It is the most commonly used test, and gives a good assessment of filling ability. It may give some indication of resistance to segregation. T50 cm test is also the measure of the speed of flow and hence the viscosity of SCC (EFNARC, 2002). This test, which was developed in Japan, was originally used to measure underwater concrete and has also been used to measure highly flowable concretes (Al-Jabri, 2005).

The slump flow test is used to determine filling ability and can indicate segregation resistance of SCC to an experienced user (Al-Jabri, 2005). Table 11 shows the results of slump flow tests. The values of (D) represent the maximum spread (slump flow final diameter), while the values of T50 represent the time required for the concrete flow to reach a circle with 50 cm diameter) (show Figure 2).

This table shows that the results were acceptable with criteria for Self-Compacting Concrete (JSCE, 1999), and illustrated that the filling ability decreased when adding steel fibers to the concrete

## Testing of Hardened Concrete

### *Compressive Strength*

The compressive strength test was carried out according to BS 1881: part 116:1989. This test was measured on 100 mm cubes using electrical testing machine with capacity of 2000 kN) (see Figure 3). The test was conducted about at ages of 28 days for nonfibrous concrete, and about at ages of 37 days for fibrous concrete. Figure 4 shows the result of compressive strength for all mixes.

### *Splitting Tensile Strength*

The splitting tensile strength test was performed according to ASTM C 496-86. (100×200) mm cylindrical concrete specimens were used. The specimens were tested using an electrical testing machine with capacity of 2000 kN) (see Figure 5). Figure 6 illustrated the result of splitting tensile strength for all mixes.

**Table 11: Slump Flow Test and Acceptance Criteria for Self-Compacting Concrete**

| | Name | T50 (s) | D (cm) | Acceptance criteria for Self-compacting Concrete | | | |
|---|---|---|---|---|---|---|---|
| Nonfibrous concrete | Mix1 | 6 | 63 | Typical range of values | | | |
| | Mix2 | 4 | 64.5 | Slump Flow by Abrams Cone | | T50cm Slump Flow | |
| | Mix3 | 3 | 64 | Max. (mm) | Min. (mm) | Max. (mm) | Min. (mm) |
| Fibrous concrete | Mix F1 | 9 | 61 | T50=3 | T50= 25 | D=600 | D=800 |
| | Mix F2 | 6 | 62 | | | | |
| | Mix F1 | 5 | 61.5 | | | | |

**Figure 2: Slump Flow Test**

**Figure 3: Compressive Strength Test**

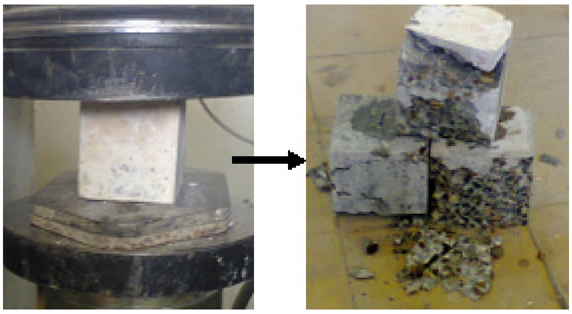


**Figure 4: Results of Compressive Strength**

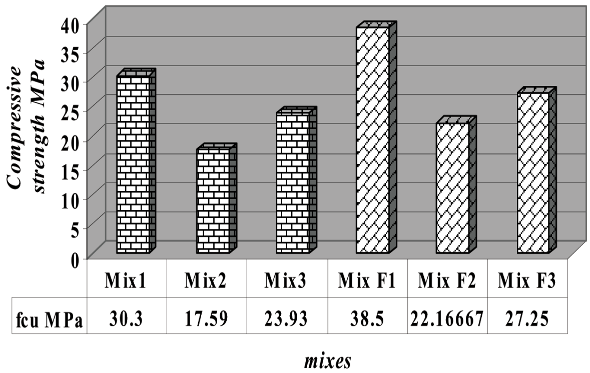



**Figure 5: Splitting Tensile Strength Test**

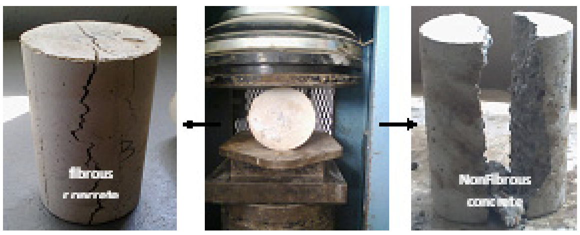
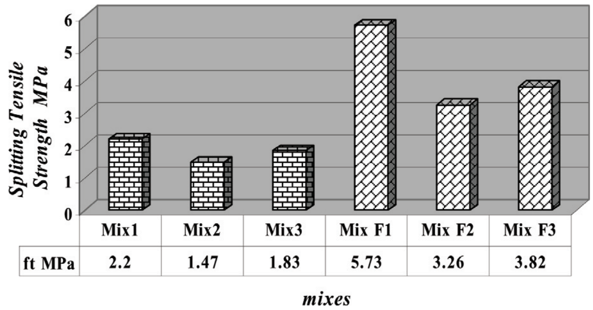


**Figure 6: Results of Splitting Tensile Strength**




## *Unit Weight (Density)*

The unit weights of nonfibrous and fibrous series were measured at right after 28-day curing, using the Equation (1), shown in Figure 7.

$$density = \frac{W_A}{W_A - W_W} \qquad ...(2)$$

where $W_A$ =weight in air, $W_W$ = weight in water

**Figure 7: Unit Weights Test**

Figure 8 show the result of Unit weight (density). The effect of steel fiber on increasing the density of concrete specimens which is also reported by Libre *et al* (2012). Table 12 show testing results of the compressive strength, splitting tensile strength and Unit weight of nonfibrous and fibrous concrete [vf =0.8%]. All these properties were obtained by using 100 mm cubes and (100×200) cylinder.

**Figure 8: Results of Unit weight (density)**

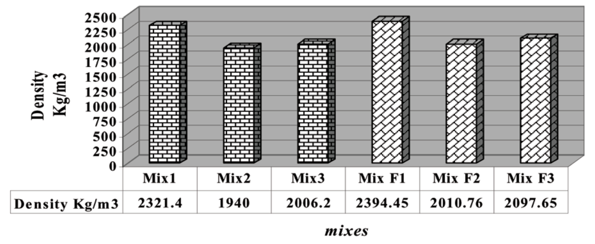



Figure (8) Results of Unit weight (density)

## Discussion

### *Effect of Replacing Normal Weight Aggregate to Light Weight Aggregate (Fine and Coarse)*

Table 12, shows that when replacing the normal sand to lightweight fine aggregate by volumetric (mix3 comparing with mix1), the ratios of redaction in compression strength, splitting tensile strength and density were (21%), (16.8%) and (13.5%), respectively. These ratios was very good comparing to the ratios of reduction when replacing the normal gravel to lightweight coarse aggregate by volumetric (mix2 comparing with mix1), these ratio (41.9%), (33.18%) and(16.4%) are for compression strength, splitting tensile strength and density respectively.

The same results were obtained when adding steel fibers (for fibrous concrete).

**Table 12: Results of the Compressive Strength, Splitting Tensile Strength and Unit Weight of Nonfibrous and Fibrous**

| | Name | $f_{cu}$ MPa | Percentage of Decrease | $f_t$ MPa | Percentage of Decrease | Density kg/m$^3$ | Percentage of Decrease |
|---|---|---|---|---|---|---|---|
| Nonfibrous concrete | Mix1 | 30.3 | – | 2.2 | – | 2321.4 | – |
| | Mix2 | 17.59 | 41.9 | 1.47 | 33.18 | 1940 | 16.4 |
| | Mix3 | 23.93 | 21.0 | 1.83 | 16.8 | 2006.2 | 13.5 |
| Fibrous concrete | Mix F1 | 38.5 | – | 5.73 | – | 2394.5 | – |
| | Mix F2 | 22.166 | 42.4 | 3.26 | 43.1 | 2010.8 | 16 |
| | Mix F3 | 27.25 | 29.09 | 3.82 | 33.3 | 2097.7 | 12.4 |

**Figure 9: Effect of Replacing Normal Weigh Aggregate to Light Weight Aggregate on the Compressive Strength, Splitting Tensile Strength and Unit Weight of Nonfibrous and Fibrous**

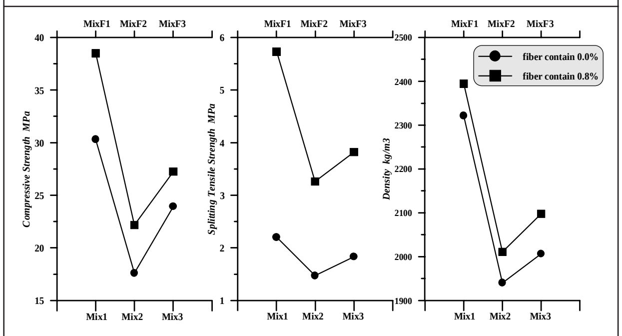



**Figure 10: Effect of Steel Fiber - Volume Fraction ($V_f$)=0.8 % on Compressive Strength, Splitting Tensile Strength and Unit Weight**

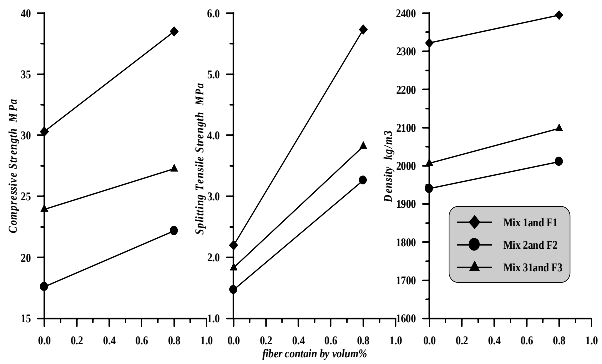


**Table 13: Effect of Steel Fiber - Volume Fraction ($V_f$)=0.8% on Compressive Strength, Splitting Tensile Strength and Unit Weight**

| Name | $f_{cu}$ MPa | Percentage of Increase | $f_t$ MPa | Percentage of Increase | Density kg/m$^3$ | Percentage of Increase |
|---|---|---|---|---|---|---|
| Mix1 | 30.3 | – | 2.2 | – | 2321.4 | – |
| Mix F1 | 38.5 | 27 | 5.7 | 1.59 | 2394.5 | 3.14 |
| Mix2 | 17.6 | – | 1.47 | – | 1940 | – |
| Mix F2 | 22.2 | 26.1 | 3.3 | 1.24 | 2010.8 | 3.64 |
| Mix3 | 23.9 | – | 1.83 | – | 2006.2 | – |
| Mix F3 | 27.3 | 14.2 | 4.14 | 1.26 | 2097.7 | 4.56 |

Figure 9 shows the testing results of the compressive strength, splitting tensile strength and unit weight of nonfibrous and fibrous concrete.

### *Effect of Steel Fiber Content*

The effect of steel fiber – volume fraction ($V_f$) of (0.8%) on compression strength, splitting tensile strength and density for three mixes [(mix1 and mixF1) for normal concrete, (mix2 and mix F2) for normal sand and lightweight coarse aggregate, (mix3 and mixF3) for lightweight fine aggregate and normal coarse aggregate] shown in Figure 10 and Table 13. This table show that the effect of steel fiber on three mixes are significantly in compressive strength [generally the inclusion of steel fiber to LWAC increases the compressive strength. But, inclusion of steel fiber more than 2% volume fraction may reduce it (Hassanpour, 2012)] and very significant in splitting tensile strength and slightly significant in density. The effect of steel fiber on compression and tensile strength for mix 3 is smaller than the effect on mix1 and mix2.

## CONCLUSION

1. The percentage of the decreasing in compression strength and Splitting Tensile Strength for mix2 (which contain normalweight sand and replacing natural river gravel to Porcelinite coarse aggregate) was higher than the percentage of the decreasing for mix3 (which contain natural river gravel and replacing sand to Porcelinite fine aggregate), these decreases depend on reference mix (which includes normalweight, sand and natural river gravel).
2. The percentage of the decreasing in unit weight (density) in mix2 and mix3 approximately equal
3. The same result of (point1 and point2) above was obtained in mixF3 (replacing sand to Porcelinite fine aggregate with steel fiber) and mixF2 (replacing natural river gravel to Porcelinite coarse aggregate with steel fiber) depend on reference mix (mixF3 that contain normalweight, sand and natural river gravel with steel fiber).

4. When the steel fiber volume fraction was increased, the compression strength increased. The percentage the increasement becomes higher in mixF1and mixF2

5. Splitting Tensile Strength is extremely increased when the steel fiber was added, The percentage of the increasement becomes higher in mix F1, but slight increasement in Unit weight (density).

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