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Properties of Concrete Produced Using Locally Available Aggregates in Libya

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Abstract: The majority of the volume of concrete is aggregates and it consists about 70% of total volume of concrete. Moreover, coarse aggregate is the source of concrete strength, controls its cost, resist weather conditions and has direct effect on concrete quality. While, fine aggregate (sand) is to filling the gaps between coarse aggregate and increase concrete workability. For that, the different types of aggregate sources should be considered and it is worth to study their effects on concrete properties.
This paper aims to study and compare the properties of concrete made using two different types of coarse aggregates (Sirte and Al-Jufra aggregate) and three different types of fine aggregates (Sabha, Waddan and Zalah sand) brought from central and southern regions of Libya.
The results showed that Al-Jufra aggregate has mechanical properties and strength better than Sirte aggregate. This result is reflected on Al-Jufra aggregate based concrete performance.
The results illustrate a variation in the impact of the sand types on the properties of concrete in terms of compressive and tensile strength of concrete
Key words — Aggregate, Sabha, Waddan, Zalah, Libya, Sand, Concrete, Quarries.

I. INTRODUCTION

All The natural resources around the world are the fundamental item for the development and economic growth; hence, it is important to put a wise plans and optimum ways to exploit such resources. Concrete is one of the highest consumed materials around the world [1]. For that, this high consumption rate of such material should be supported by extensive researches about concrete properties development and its technologies.

Concrete is widely used because there is no alternative materials can serve the huge urban expansions around the world. Moreover, manufacturing the concrete is simple and easier than other materials.

In Libya, the reinforced concrete is considered the main construction material. The reports indicate that 79% of structures were constructed by using cement-based materials [2] . A very fast development has been expected in construction industry in Libya in the near future [3], to compensate the long stop of planed urban development and the huge demand of construction materials.

These demands require high quality and enough quantities of materials with good performance. On the top of these materials is the aggregate, which is available with huge deposit in Libya. However, the quality of aggregates is varying from one location to another depending on the quality the source rocks.

Despite that aggregate is a filling material, but it has very effective role in produced concrete properties such as durability, workability, tensile strength and compressive strength. The type and properties of fine and coarse aggregate have great effects on the hardened concrete performance, because it consists a large percentage of concrete volume [4].

Libya extends over 1.76 million square kilometers and there are 329 coarse aggregate quarries and 84 sand quarries dispersed across this area [5], and flourishing of quarries industry is expected to associate the expected urban developments. The different sources of aggregate results in different performance and various properties, which require more studies about the properties of available aggregate types.

For that, and because of the lack of local studies in this area, further studies are required to determine the properties of concrete produced using locally available aggregates in Libya.

The aim of this work is to study and compare the properties of two different types of coarse aggregate (Sirte and Al-Jufra aggregate) and three types of fine aggregates (Sabha, Waddan and Zalah sand) and their effects on hardened concrete with different aggregate ratios.

II. EXPERIMENTAL WORK

To achieve the objective of this research, the properties of coarse aggregates, fine aggregates, and concrete produced using different percentages of the aggregate were tested.

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A. Properties of Coarse Aggregates

To determine the quality of used aggregate several samples were prepared to evaluate their physical, mechanical and microscopic properties and compare the results with the American or British standards.Table 1 illustrates the results of physical and mechanical properties of coarse aggregate samples. The results have shown that the water absorption ratio of Sirte aggregate is higher than Al-Jufra aggregate. Nonetheless, both of aggregate types still have absorption ratios within the standards. In addition, all specific weights values are ranged within American specifications limits. In other words, we can say Al-Jufra aggregate is heavier than Sirte aggregate and has lower porosity and absorption.The aggregates crushing value, impact value and Los Angels abrasion resistance tests showed that both of aggregate types had good values within specifications. Furthermore, the testing results indicate that Al-Jufra aggregate has higher toughness rate and it is more suitable in concrete members that facing friction and abrasion as shown in Table1.

Table 1. Physical and mechanical properties of coarse aggregates

Test	Sirte's coarse Agg.	Al-Jufra's coarse Agg.	Limitation	Standard
Absorption ratio %	1.97	1.3	<2%	ASTM C128/C127 [14-15]
Specific weights	2.5	2.69	>2.6	ASTM C128/C127 [14-15]
Los Angels abrasion resistance %	20	17.8	<30%	ASTM C131/C535 [16-17]
Crushing value %	22.9	17.8	<30%	BS 812 Part2: 110 [18]
Impact value %	35	27	<45%	BS 812 Part2: 112 [19]

Figure 1 shows the particle size analysis of the two different types of aggregates as well as minimum and maximum limits according to the British specifications [6]. As shown in the figure 1 the gradient aggregates particle of Sirte and Al-Jufra samples remained within the limits of the specification. Table 2 summarizes normal and microscopic inspection of the aggregate samples.

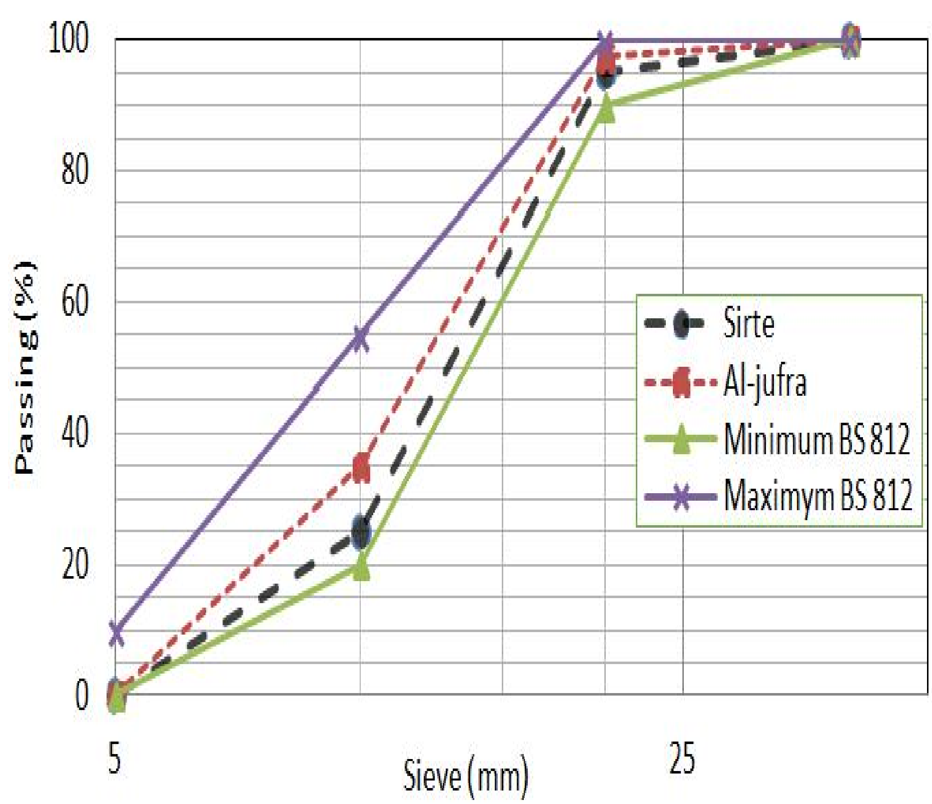

Fig 1 The particle size analysis of the two different types of aggregates

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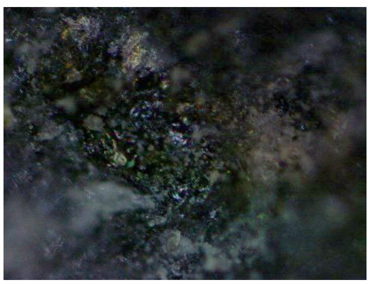
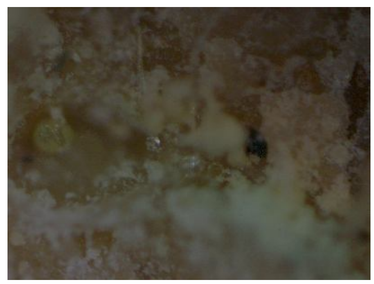
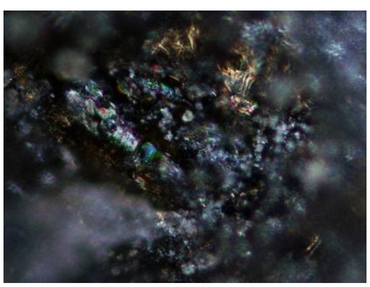
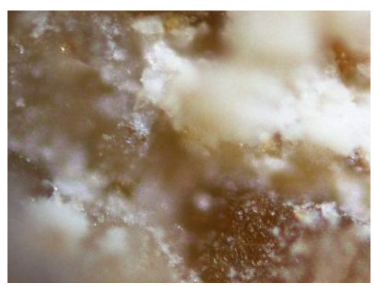
Table 2. Normal and microscopic inspection of the aggregate used

Microscopic Lens	Al-Jufra's coarse Agg.	Sirte's coarse Agg.	Comment
Normal			In both cases the tested aggregate is clearly irregular which is need more water and cement. Nevertheless, Sirte aggregate is more uniform than Al-Jufra aggregate.
10X			The external surface of Sirte aggregate has higher porosity and full with sediments and salts comparing to Al-Jufra aggregate. These sediments work as separation layer between the aggregate and cement which results in low concrete quality.
20X			Sirte Aggregate contains mix of colours that reflects minerals consisting the aggregate. The main colour of Al-Jufra aggregate is black and reflect it is volcanic origin.

B. Properties of Fine Aggregates

The three types of sand used in the study is illustrated in figure 2. The specific weight, moisture content, liquid limit and sieve analysis tests of the tree fine aggregates samples were conducted. The results showed that the moisture content of the samples are 0.08% for Sabha sand, 0.17% for Waddan sand and 0.63% for Zalah sand as shown in figure 3. Additionally, as shown in figure 4 the results of specific weight test of Zalah and Waddan sands were 2.63 and 2.65 respectively. These results leys within British standards (2.5 to 2.6) (BS 812: Part 2: 1995. However, Sabha sand had specific weight of 2.72 which slightly exceeds the allowed limit.

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Fig 2 Types of sand used in the study

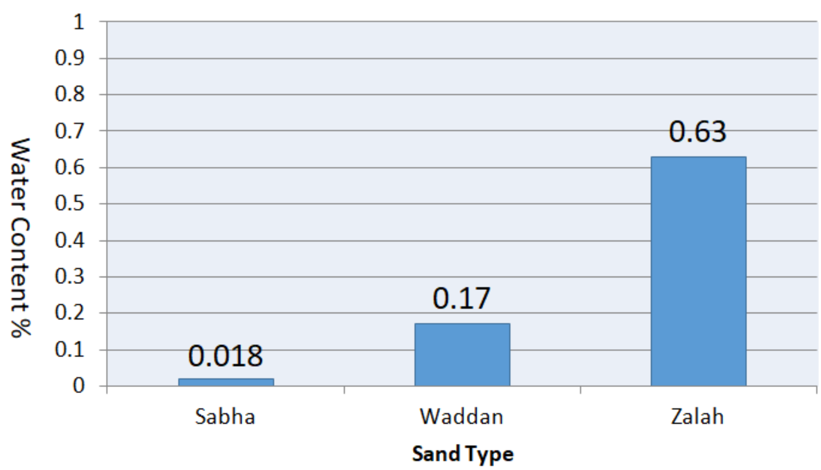

Fig 3: Moisture content of sand samples

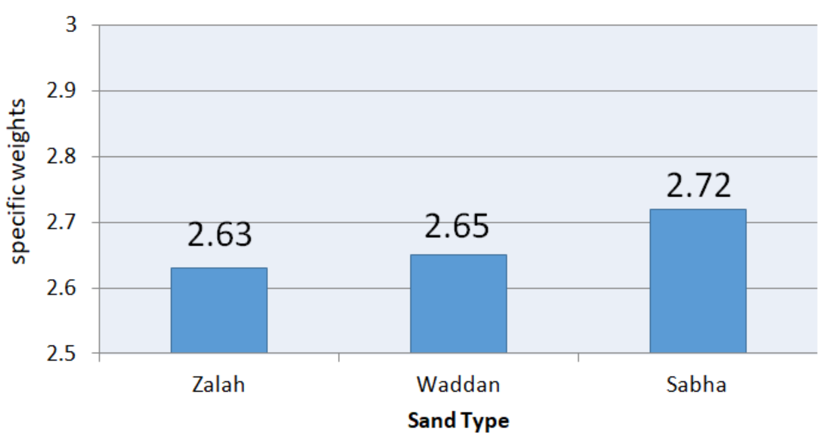

Fig 4 Specific weights of sand samples

Liquid limit value using cone penetrometer test was conducted. The results demonstrated that Sabha sand has the lowest water content percentage with (8.12 %); while Waddan and Zalah sands showed higher percentages with 16.34% and 8.52% respectively. Thus, Sabha sand needs less water during the concrete mixing. Figure 5 illustrate the liquid limit values for the sand samples.

After carrying out the experiments to determine the particle size analysis of all sand samples the results showed that Zalah sand particles passed 1mm, 2mm and 4mm sieves with percentages of (99.54 %, 97.28 % and 87.24 %) respectively. These percentages are lower than the results of Waddan and Sabha sand samples.

The percentages of Sabha sand samples that passed the Sieves of size (0.075mm, 0.15mm) are 1.72% and 35.52% respectively. This result means that Sabha sand is finer than Zalah and Waddan sands.

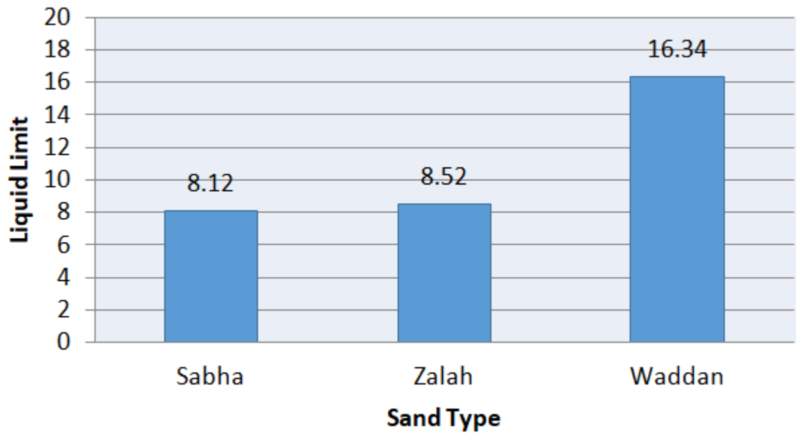

Fig 5 Liquid limit for sand samples

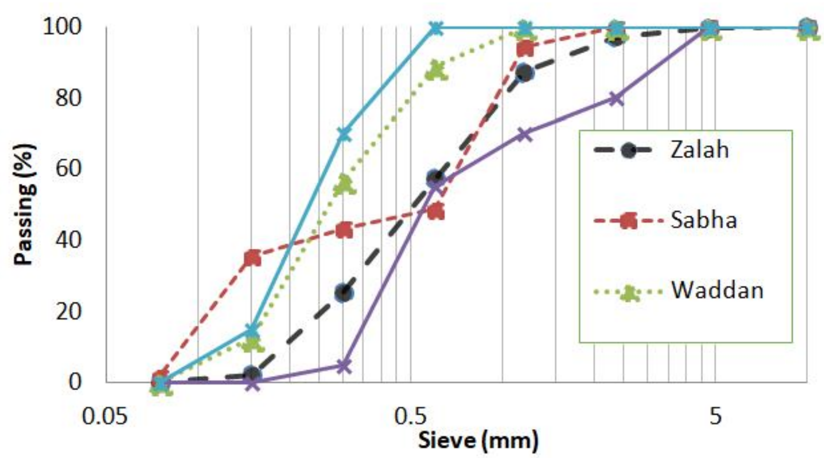

Fig 6 The particle size analysis of the three sand types

Figure 6 demonstrates the particle size analysis of the three sand types, the minimum and maximum limits according to British standards 6. We can confidently say that the particle size of Waddan and Zalah sands are within the allowed specifications limits. On the other hand, it is clear that the Sabha sand is not within the allowed limits.

C. Properties of Concrete

The properties of fresh and hardened concrete were evaluated in two series. Different percentages of coarse and fine aggregates were examined in the first and second series, respectively.

1) *Properties of Concrete Using Different Types of Coarse Aggregates:* In the first series of concrete samples, two groups of concrete samples for each type of coarse aggregate (Sirte and Al-Jufra) were prepared. 24 concrete cubic samples of 150mm×150mm×150mm have been tested to find out the compressive strengths [7]. Additionally, 24 cylindrical concrete samples of 150mm×300mm have been tested to find out the indirect tensile strengths [8].In order to have one variable (coarse aggregates) in this section of the experimental program, only one type of fine aggregate (Waddan natural sedimentary sand) was used in the concrete mixture. Pure drinkable water compatible with the Libyan specifications [9] was used for mixing and curing concrete samples[10]. Additionally, Portland cement produced according Libyan specifications [11] was used. The cement was examined for the fineness (using sieve No. 200) and the result was: 19.1% (<22%) which complies with ASTM C 150 [12]The concrete was mixed, then casted in the laboratory in three layers and mechanical vibration table was used for 10 seconds in every layer. After that, the samples were left in the laboratory for 24 hours, then the samples were cured in water for 7 and 28 days. Table 3 demonstrates the concrete samples properties.

Table 3: First series concrete mixture ingredients

Mixture	Cement	Sand	Al-Jufra	Sirte	w/c
Sirte (reference)	1	2	0	2.5	0.65
Sirte (16%)	1	2	0	2.9	0.65
Sirte (32%)	1	2	0	3.3	0.65
Al-Jufra (reference)	1	2	2.5	0	0.65
Al-Jufra (16%)	1	2	2.9	0	0.65
Al-Jufra (32%)	1	2	3.3	0	0.65

2) *Slump Test Results*: Table 4 demonstrates the laboratory results of slump test. The concrete samples which contains Sirte aggregate showed lower slump rate. This result reflects higher absorption rate of Sirte aggregate comparing to Al-Jufra aggregate. However, all of tested samples showed results within acceptable range and both aggregate types had a slight effect on fresh concrete.

Table 4. First series slump test results

Sample **(%)**	Slump of Sirte Agg. concrete (mm)	Slump of Al-Jufra Agg concrete (mm)
5.0	95	100
0.0	90	90
7.4	88	95

3) *Compressive Strength Test Results:* This is one of the most significant test that is used to estimate the strength of hardened concrete [13]. After curing process, the samples were left to become dry. Then, the samples have been tested to determine their failure load and calculate the average compressive strength. Figure 7 illustrates the compressive strengths after 7 and 28 days of curing.In general, the results demonstrate that the samples which contains Al-Jufra aggregate have compressive strength higher than samples which are contains Sirte aggregate. Moreover, the increase rate of compressive strength in the samples that have 32% increase of aggregate are less than samples that have 16% increase of aggregate for both tested aggregate types.

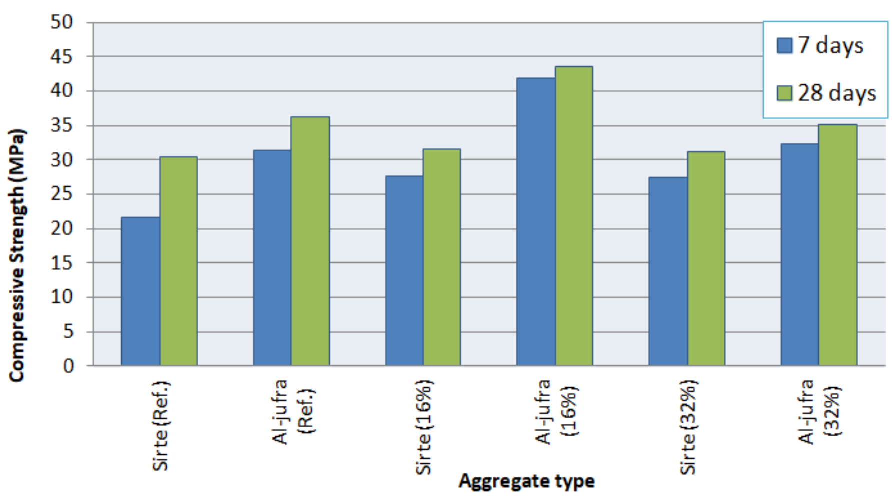

Fig 7 Results of Compressive Strength Test Cubic Samples

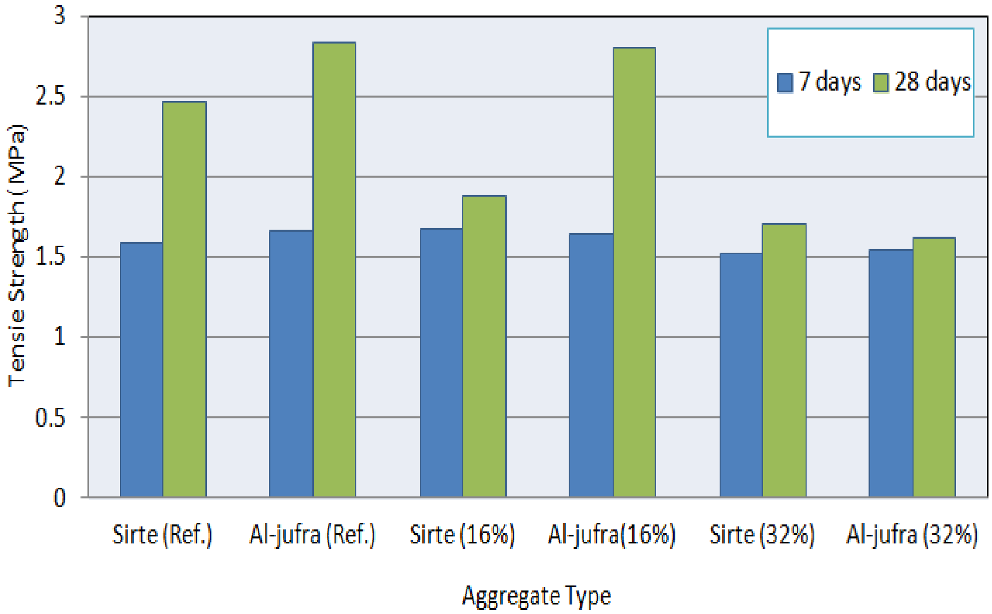

Fig 8 The tensile strengths of the three samples groups after 7 and 28 days

4) *Indirect Tensile Strength Test Results:* Tensile strength of concrete is noticeably affected by used aggregate properties. Figure 8 demonstrates the tensile strengths of the three samples groups after 7 and 28 days of curing. However, the concrete tensile strength is low; normally it is ranged from 8% to 12% of compressive strength. The results collected from tests showed that Al-Jufra aggregate samples have tensile strength larger than concrete samples, which contains Sirte aggregate. Additionally, increase ratio of used aggregate is inversely related to indirect tensile strength.

D. Properties of Concrete Using Different Types of Fine Aggregates

In the second series of concrete testes, three groups of concrete samples were prepared by using the three sand types. 12 concrete cubic samples of size 150 mm x 150 mm x 150 mm to test the compressive strength, also 12 cylindrical samples of size 150 mm x 300 mm to test the indirect tensile strength.As in the first series experimental tests, only one variable (fine aggregates) aimed to be examined, and one type of coarse aggregate (Al-Jufra volcanic coarse aggregate) was used in the concrete mixture. Pure drinkable water compatible with the Libyan specifications 9 was used for mixing and curing concrete samples. Additionally, Portland cement produced according Libyan specifications [11] was used. The cement was examined for the fineness (using sieve No. 200) and the result was: 19.1% (<22%) which complies with ASTM C 150 [12].The samples were mixed, then casted in the laboratory in three layers and mechanical vibration table was used for 10 seconds in every layer. After that, the samples were left in the laboratory for 24 hours, the samples were cured in water for 7 and 28 days. Table 5 demonstrates the concrete samples components.

Table 5. Second series concrete mixture ingredients

Cement (kg/m^3)	Fine aggregates (kg/m^3)	Coarse aggregates (kg/m^3)	W/c
350	700	1050	0.64

1) *Fresh Concrete Slump Test Results:* From the results we noted that Zalah, Sabha and Waddan sand samples have almost slight variance (60, 65, 70) respectively. These results are within the limits of medium workability mixes. hence, the change of sand type has not clear effect on the Slump of fresh concrete.
2) *Compressive Strength Test Results:* Figure 9 shows the Compressive Strength of the three concrete mixes samples after 7 and 28 days of curing. Generally, the results demonstrate that the Waddan samples have higher compressive strength than Zalah and Sabha samples. Moreover, the findings prove that the compressive strength increase ratio of Sabha samples is less than Waddan and Zalah samples.

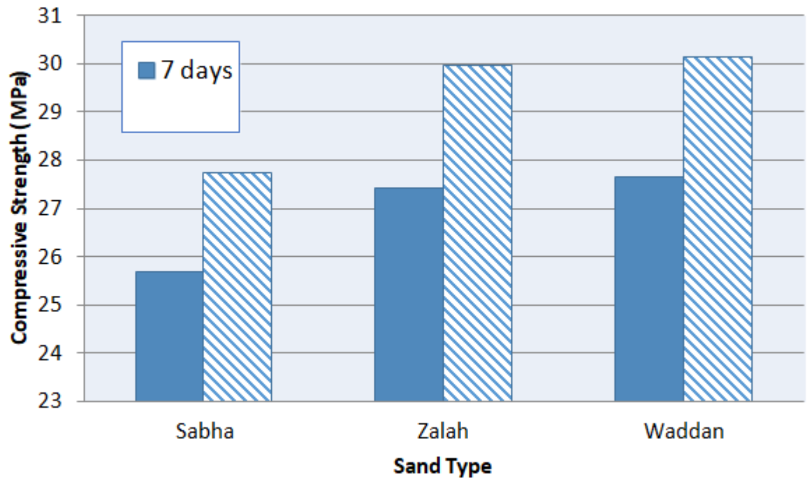

Fig 9 Compressive strength of cubic samples

3) *Indirect Tensile Strength Test Results:* As shown in Figure 10, the concrete tensile strength is affected by used sand particles. It is well known that the concrete has low tensile strength. The concrete tensile strength ranged between 8% and 12% of its compressive strength. Based on test results we found that Zalah sand concrete samples showed the highest tensile strength. Furthermore, the tensile strength increase rate clearly was lower than the other cubic samples.

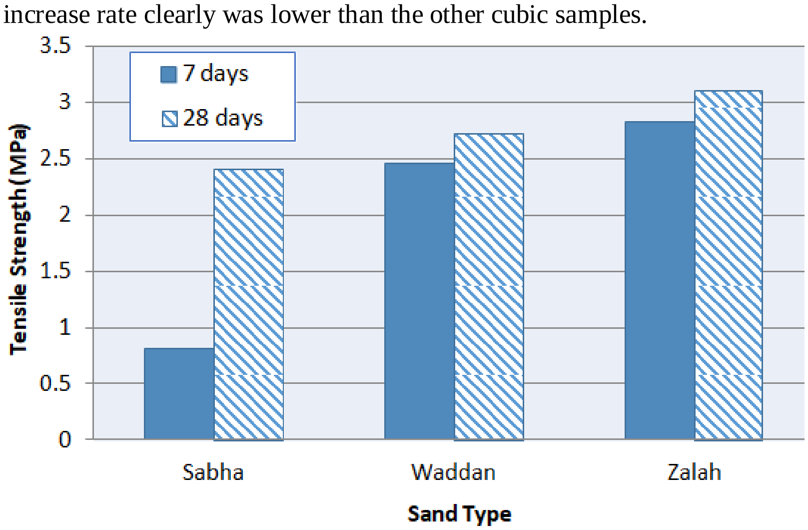

Fig 10 Indirect Tensile Strength of Cylindrical Samples

III. CONCLUSION

Knowing mechanical properties of aggregate is very supportive to determine its validity and optimum usage. In this research paper, an experimental program has been conducted to study the mechanical, physical, microscopic properties of some types of aggregates that are commonly used in the southern and central parts of Libya. The impact of utilizing two types of coarse aggregate (Sirte gypsum aggregate and Al-Jufra volcanic aggregate), and three types of fine aggregates (Zalah sand, Waddan sand and Sabha sand), have been investigated and the following conclusion can be made:

A. Al-Jufra aggregate have better mechanical properties based on its low absorption ratio comparing to Sirte aggregate which is more porous (i.e. higher sensitivity to water). The higher porosity of Sirte aggregate means lower compressive and tensile strength.

B. Al-Jufra aggregate showed high strength to impact loads and abrasion because of its rough surface. Hence it is very appropriate to heavy duty concrete members.

C. Concrete contains 16% of aggregate have higher compressive and tensile strength comparing to concrete contains 32% of aggregate. This result was expected because of decreasing the bond material between aggregate particles.

D. Zalah sand contains rougher particles comparing to Waddan and Sabha sands, and Waddan and Zalah sand stays within British standards whereas Sabha sand exceeded the specifications limits.

E. The specific weight of Zalah and Waddan sands conforms the British specifications. However, Sabha sand slightly exceeds the allowed limits.

F. The concrete made using Waddan sand has a higher compressive strength than the other two types.

G. The concrete made using Zelah sand has the highest tensile strength than the other two types.

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