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# *Experimental Investigation of the Influence of Different Fine Aggregate Sources on Mechanical and Physical Properties of Concrete*

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**Abstract**

This study investigates the effect of different fine aggregate sources (Qranilia, Sidi Al-Sayeh, and Zliten sands) on the compressive strength development of concrete at 7, 14, and 28 days. A constant mixed design was adopted in order to isolate the influence of sand properties on mechanical performance.

Experimental results show significant variation in compressive strength depending on sand source. Qranilia sand consistently achieved the highest strength values, while Zliten sand exhibited the lowest performance. The findings confirm that fine aggregate characteristics such as grading, particle packing, and specific gravity significantly influence the microstructure and load-bearing capacity of concrete.

## 1. Introduction

Concrete is the most widely used construction material in civil engineering due to its versatility and structural performance. Its mechanical properties are highly dependent on the quality and characteristics of its constituent materials, particularly fine aggregate (sand), which typically constitutes a significant portion of the concrete volume [1], [2].

Fine aggregate plays a critical role in determining the workability, density, and compressive strength of concrete. Unlike coarse aggregate, sand significantly influences particle packing density, void content, and the quality of the interfacial transition zone (ITZ) between cement paste and aggregate particles [2], [3].

Previous studies have demonstrated that variations in aggregate grading, shape, and specific gravity can lead to noticeable changes in compressive strength, even when mix proportions remain constant [3], [4]. This is because the internal microstructure of concrete is highly sensitive to particle distribution and packing efficiency.

The interfacial transition zone (ITZ) is considered the weakest region in concrete, and its properties strongly affect the overall mechanical performance of the material. A well-graded fine aggregate reduces ITZ porosity and improves stress transfer between cement paste and aggregates, resulting in higher compressive strength [2], [5].

Based on this background, the present study investigates the influence of three different local sand sources (Qranilia, Sidi Al-Sayeh, and Zliten) on the compressive strength development of concrete at different curing ages (7, 14, and 28 days), while keeping all other mix parameters constant.

## 2. Materials and Experimental Program

### 2.1 Materials

- Ordinary Portland Cement (OPC)
- Potable water
- Constant coarse aggregate source
- Fine aggregates:
- Qranilia sand
- Sidi Al-Sayeh sand
- Zliten sand

### 2.2 Mix Design (per m³)

- Water: 225 kg
- Cement: 450 kg
- Fine aggregate: 596.75 kg
- Coarse aggregate: 1108.25 kg

**Table (1) shows the concrete mixed materials per cubic meter**

| mix materials | Weight per unit volume ($kg/m^3$ ) |
|---|---|
| water | 225 |
| cement | 450 |
| Fine aggregate | 596.75 |
| coarse aggregate | 1108.25 |

Water/cement ratio = 0.5

### 2.3 Testing Procedure

Concrete cubes were cast and tested for compressive strength at:

- 7 days
- 14 days
- 28 days

## 3. Results

### 3.1 Compressive Strength in 7 Days (MPa)

At early age (7 days), a clear distinction in strength development is observed. Qranilia sand exhibits significantly higher compressive strength compared to the other sources, indicating better early-age hydration efficiency and improved particle packing.

The lower performance of Zliten sand suggests a higher void ratio and less efficient packing structure, which reduces the effective load-bearing area of the cement paste matrix.

**Table (2) shows the compressive strength of the concrete mix after 7 days**

| Qranilia sand | Sand sidi al-sayah | Zliten sand | Type sand |
|---|---|---|---|
| 29.5 $N/mm^2$ | 23.8 $N/mm^2$ | 19.1 $N/mm^2$ | Compressive strength Cube No.1 |
| 30.4 $N/mm^2$ | 22.8 $N/mm^2$ | 18.4 $N/mm^2$ | Compressive strength Cube No.2 |
| 29.8 $N/mm^2$ | 25.8 $N/mm^2$ | 19.8 $N/mm^2$ | Compressive strength Cube No.3 |
| 29.9 | 24.13 | 19.10 | average |

**3.2 Compressive Strength in 14 Days (MPa)**

At 14 days, all mixes show a significant increase in strength due to continued hydration. Interestingly, Sidi Al-Sayeh sand approaches Qranilia performance, which suggests improved particle interaction at intermediate curing stages.

This convergence indicates that the influence of sand source is most dominant at early and later stages, while intermediate curing reduces variability due to ongoing densification of the cement matrix.

**(3) shows the compressive strength of the concrete mix after 14 days**

| Qranilia sand | Sand sidi al-sayah | Zliten sand | Type sand |
|---|---|---|---|
| 33.3 $N/mm^2$ | 27.7 $N/mm^2$ | 25.4 $N/mm^2$ | Compressive strength Cube No.1 |
| 35.6 $N/mm^2$ | 28.7 $N/mm^2$ | 25.8 $N/mm^2$ | Compressive strength Cube No.2 |
| 35.0 $N/mm^2$ | 28.3 $N/mm^2$ | 25.4 $N/mm^2$ | Compressive strength Cube No.3 |
| 34.63 | 28.23 | 25.53 | average |

**3.3 Compressive Strength in 28 Days (MPa)**

At 28 days, Qranilia sand maintains the highest overall performance, confirming its superior contribution to long-term matrix stability. However, a slight reduction compared to 14-day values may indicate experimental variability or differences in curing uniformity, which is common in cube testing under laboratory conditions.

Despite this, the ranking of performance remains consistent:
Qranilia > Sidi Al-Sayeh > Zliten

**Table (4) shows the compressive strength of the concrete mix after 28 days**

| Qranilia sand | Sand sidi al-sayah | Zliten sand | Type sand |
|---|---|---|---|
| 39.0 N/mm$^2$ | 41.2 N/mm$^2$ | 31.3 N/mm$^2$ | Compressive strength Cube No.1 |
| 37.8 N/mm$^2$ | 41.0 N/mm$^2$ | 30.7 N/mm$^2$ | Compressive strength Cube No.2 |
| 40.5 N/mm$^2$ | 33.2 N/mm$^2$ | 30.4 N/mm$^2$ | Compressive strength Cube No.3 |
| 39.10 | 38.46 | 30.80 | average |

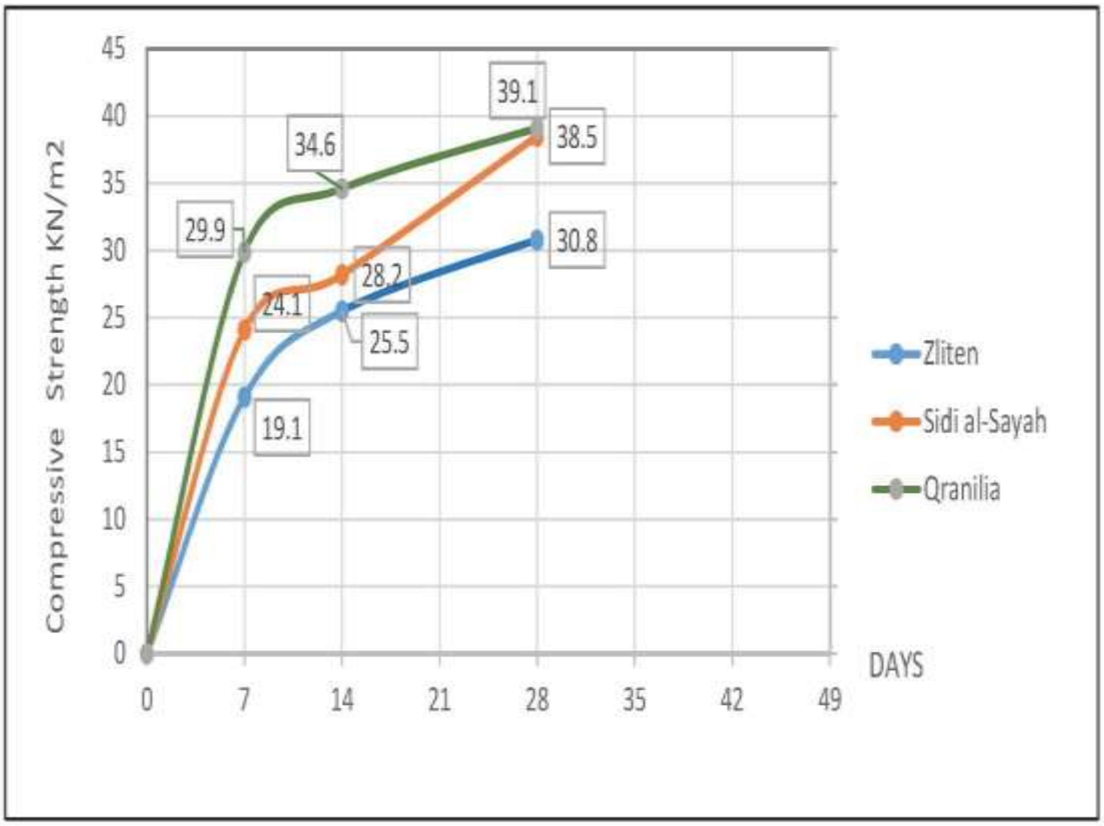


**Figure (1) shows the relation between compressive strength and No. of days**

### 3.4 Density (concrete Density)

The density results show minimal variation between mixes, indicating that the overall unit weight of concrete is not significantly affected by sand source under constant mix proportions.

However, even small differences in density are important because they reflect changes in internal void structure. Lower effective void content generally correlates with higher compressive strength.
Interestingly, Zliten sand shows the highest density but the lowest strength, which confirms that:
Higher density does not always correspond to higher strength in concrete
This is a key engineering insight, as density alone does not reflect internal bonding quality or ITZ performance.

**Table (5) shows the concrete density of mixes using sand from Zliten, Sidi Al-Sayeh, and Qranilia**

| Qranilia sand | Sand sidi al-sayah | Zliten sand | Type sand |
|---|---|---|---|
| 1369 | 1369 | 1369 | Weight of empty cube (kg) |
| 9351 | 9304 | 9435 | Weight of the white cube mixture (kg) |
| 2.36 | 2.35 | 2.38 | Concrete density ($kg/cm^3$ ) |

**Table (6) shows the specific gravity of Zliten, Sidi Al-Sayeh, and Qariniliya**

| Qranilia sand | Sand sidi al-sayah | Zliten sand | Type sand |
|---|---|---|---|
| 2.32 | 2.69 | 2.63 | الوزن النوعي |

**3.5 Specific Gravity of Sand)**

The specific gravity values indicate differences in mineral composition and particle density among the sand sources.
However, the results clearly show that:

- Higher specific gravity (Sidi Al-Sayeh and Zliten) did not produce higher compressive strength
- Lower specific gravity sand (Qranilia) produced the highest strength

This confirms a fundamental principle in concrete technology:
Mechanical performance is governed more by grading and packing efficiency than by particle density alone
Thus, specific gravity is a secondary parameter in predicting compressive strength compared to particle size distribution and void structure.

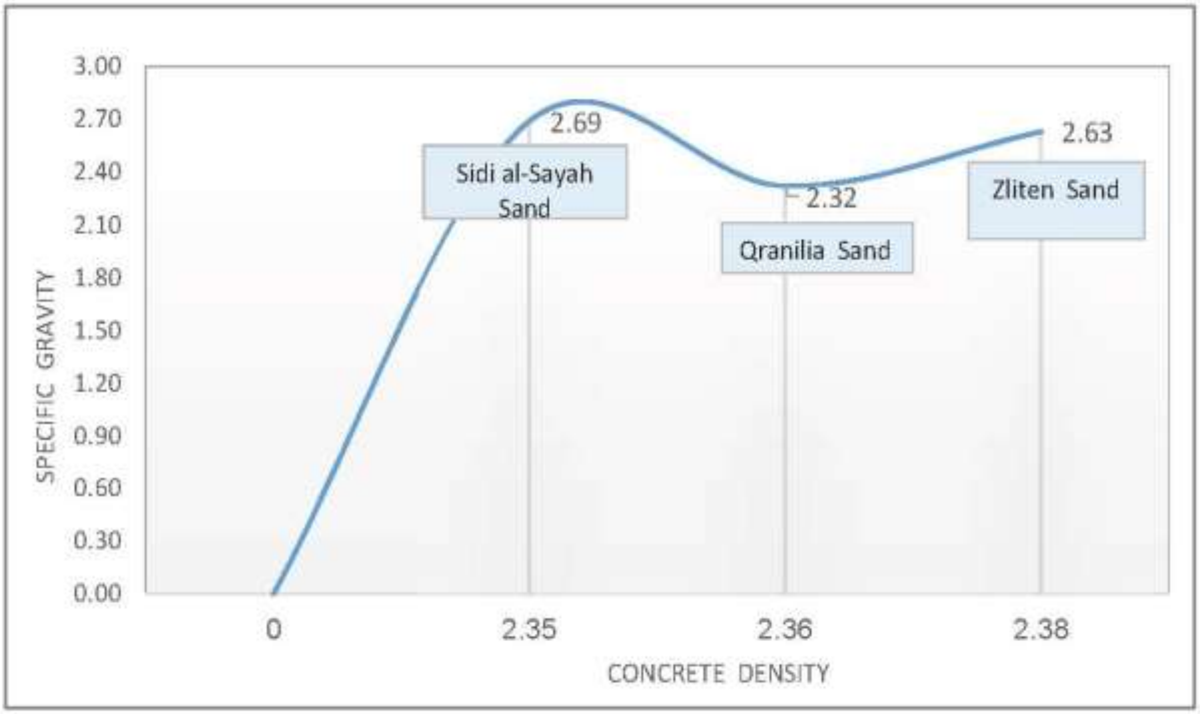


**Figure (2) shows the relation between concrete density and specific gravity**

**3.6 Integrated Engineering Interpretation**

By combining strength, density, and specific gravity results, the following engineering conclusions can be drawn:

**(1) Particle Packing Dominance**

Qranilia sand likely has better gradation, leading to:

- Reduced voids
- Higher packing density
- Stronger cement paste continuity

This directly improves compressive strength.

**4. Discussion**

The experimental results clearly demonstrate that the influence of fine aggregate (sand) source on compressive strength is not governed solely by conventional physical parameters such as density or specific gravity, but is primarily controlled by the internal microstructural arrangement of concrete, particularly particle packing and the Interfacial Transition Zone (ITZ).

Although Zliten sand exhibited the highest concrete density among the mixes, it produced the lowest compressive strength. This indicates that bulk density alone is not a reliable indicator of mechanical performance. Instead, it reflects mass distribution rather than internal bonding quality or stress transfer efficiency within the cementitious matrix.

On the other hand, Qranilia sand consistently achieved the highest compressive strength despite not having the highest specific gravity. This confirms that particle size distribution and grading quality play a more dominant role than particle density in governing concrete strength. A well-graded sand improves packing density, reduces void content, and enhances the continuity of the cement paste matrix.

The intermediate behavior observed in Sidi Al-Sayeh sand at 14 days suggests that ongoing hydration reduces performance variability between mixes over time. However, this convergence is partial, as differences in aggregate quality continue to influence long-term mechanical behavior.

From a micromechanical perspective, the improved performance of Qranilia sand can be attributed to:

- Reduced void ratio within the matrix
- Improved particle interlock and packing efficiency
- A denser and thinner Interfacial Transition Zone (ITZ)
- Enhanced stress transfer between cement paste and aggregate

These factors collectively lead to improved load-bearing capacity and delayed microcrack initiation under compressive loading.

Overall, the findings highlight that fine aggregate quality should not be treated as a secondary mix parameter, but rather as a critical design variable that significantly influences structural performance and durability of concrete.

### 4.1 Effect of Particle Packing and Void Reduction

The variation in compressive strength is primarily attributed to differences in particle packing efficiency of the fine aggregates. Well-graded sand improves packing density, reduces void content, and enhances cement paste continuity.

Qranilia sand likely exhibits a more favorable gradation, resulting in:

- Lower void ratio
- Improved particle interlock
- Higher density matrix formation

These factors directly enhance compressive strength.

### 4.2 Interfacial Transition Zone (ITZ) Quality

The ITZ is known as the weakest region in concrete microstructure. A well-graded sand reduces ITZ thickness and porosity, resulting in improved load transfer between cement paste and aggregate.

The superior performance of Qranilia sand suggests a denser ITZ compared to the other sand sources.

### 4.3 Role of Specific Gravity

Although Sidi Al-Sayeh sand exhibits higher specific gravity, this does not necessarily correlate with higher strength. This confirms that:

Particle grading and packing density are more influential than density alone in determining compressive strength.

### 4.4 Strength Development Behavior

The expected trend is an increase in compressive strength with curing age. However, minor inconsistencies observed at 28 days may be attributed to:

- Experimental variability in cube compaction
- Curing condition differences
- Natural scatter in concrete testing results

Despite this, Qranilia sand consistently demonstrates superior overall performance.

### 4.5 Engineering Implications

The results indicate that changing sand source alone can lead to strength variations exceeding 40%, which is highly significant for structural design.

This highlights that fine aggregate selection should not be treated as a secondary parameter but as a critical design factor influencing structural safety and durability.

## 5. Conclusions

1. Fine aggregate source has a significant impact on compressive strength.
2. Qranilia sand produced the highest strength values across all curing ages.
3. Zliten sand showed the lowest performance.
4. Particle packing and grading are more influential than specific gravity.
5. Fine aggregate selection is critical for structural concrete performance.

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