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# Studying the Effect of Incorporating of Souknah (Al-Jufra) Limestone (SLS) on the Compression Strength of Hardened Cement Mortar

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Cement Mortar
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**A B S T R A C T**

Mortar is the bonding agent that integrates brick into a masonry assembly. Mortar must be strong, durable, and capable of keeping the masonry intact, and it must help to create a water-resistant barrier. The qualities, quantities, and content of the components in the mortar affect these needs. The purpose of this study is to compare the compressive strength and engineering qualities of Soukanah (Al-Jufra) limestone (SLS) when it is partially substituted for Portland cement powder in mortar. Limestone substituted in part for cement is regarded as 5, 10, 15, 20, 25, 30, 35, and 40%. Samples of hardened cement mortar are tested for compressive strength after 28 days of age. The greatest compressive strength is only reached at 5% replacement, according to the results. This finding makes it evident that (SLS) can be used as a good 5% replacement for cement in cement mortar mixtures.

# دراسة تأثير إضافة الحجر الجيري بمنطقة سوكنة (الجفرة) على مقاومة إنضغاط الملاط الأسمنتي المتصلب

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**الكلمات المفتاحية:**
الحجر الجيري
الملاط الأسمنتي
الكثافة
الوزن النوعي
مقاومة الإنضغاط

**الملخص**

الملاط الأسمنتي هو المادة الهامة في ربط قوالب البناء ببعضها. الملاط الأسمنتي يجب أن يكون قوي ومتينا وقابلا على أن يجعل البناء متماسكا، كما يجب أن يساعد في عمل حاجز لمقاومة تسرب الماء. هذه المتطلبات تتأثر بشدة بتركيب ونسب الخلط وكذلك خواص الملاط الأسمنتي. أجريت دراسة الخواص الميكانيكية وذلك بإختبار مقاومة الملاط الأسمنتية للإنضغاط عند الاستبدال الجزئي لمادة الأسمنت بخام الحجر الجيري لمنطقة سوكنة. نسب استبدال مادة الأسمنت بالحجر الجيري لمنطقة سوكنة كان على النحو التالي (5 و 10 و 15 و 20 و 25 و 30 و 35 و 40 %). وتم اختبار مقاومة الإنضغاط للعينات الأسمنتية المتصلبة بعد غمرها في الماء لمدة 28 يوما. بناء على نتائج اختبارات مقاومة ا الإنضغاط تبين أن أقصي مقاومة للإنضغاط كانت عند نسبة استبدال 5%. وتدل النتائج بصورة واضحة أن إضافة الحجر الجيري لمنطقة سوكنة الى خلطة الملاط الأسمنتي بنسبة لا تزيد عن 5% يعطي نتائج مقاومة إنضغاط جيدة.

## 1. Introduction

In the cement industry worldwide, the production of Portland limestone cement—which uses limestone filler to partially replace clinker—is currently popular. This trend is particularly evident in European nations because of the cement's numerous benefits, which include lower production costs, higher cement productivity, and environmental protection thanks to a notable decrease in $CO_2$ and $NO_2$ emissions per ton of cement produced [1]. For a long time, various parts of the world have used limestone powder in concrete, but it is currently regaining popularity worldwide. It is usually sold as calcium carbonate in the calcite polymorph and comes in different magnesium (carbonate) percentages. Limestone is widely used in the concrete industry due to its role as the primary source of calcium for cement manufacture and because it is one of the most often used aggregates [2]. The crystal structure of the calcium oxide (CaO) system's rock

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salt and the characteristics of lime stone are depicted in Figure 1 and Table 1, respectively. This paper aims to investigate the impact of partially substituting Soukanah limestone (SLS) for cement material on the compressive strength of cement mortar. (SLS) percents are used to replace cement at different rates: 5, 10, 15, 20, 25, 30, 35, and 40%. Up to 28 days of age, compressive strength is assessed and compared.

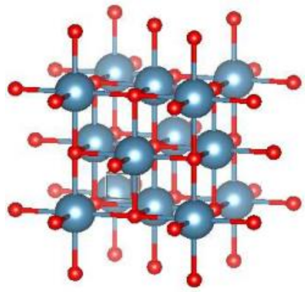

**Fig. 1:** Crystal Structure of the Rock Salt of the Cacium Oxide (CaO) System. [3].

**Table 1: Limestone Chemical Properties [4].**

| Content | Percent (%) |
|---|---|
| Lime (CaO) | 38 – 42 |
| Quartz (Silica) (SiO2) | 20 – 25 |
| Alumina (Al2O3) | 2.0 – 4.0 |
| Other Oxides (Mg, Na) | 1.5 – 2.5 |
| Ignition Lost | 30 – 32 |

**Table 2:** Limestone Physical Properties [4].

| Colour | White |
|---|---|
| Specific Density | 2.5 – 2.65 kg/cm |
| Water Absorption | Less than 1 % |
| Porosity | Small |
| Hardness | 3.0 – 4.0 |
| Compression Stress | 1800 – 2100 kg/cm³ |

For use in the production of masonry mortar for brick, block, and stone masonry construction, mortar cement is a particularly blended and produced product. Although they contain less air than masonry cements and are required to meet a minimum bond strength, mortar cement mortars share many characteristics with masonry cement mortars [5].

For structural applications requiring masonry with a high flexural bond strength, mortar cement mortars are suitable. In order to improve one or more characteristics, such as setting time, workability, water retention, and durability, additional components are added to the Portland cement or blended hydraulic cement mixture, along with plasticizing agents such as hydrated lime or limestone [5].

## 2. Literature Review

Kropyvnytska T., (2021), The article demonstrates the connection between cement production and sustainability, demonstrating how limestone additives can be used in place of clinker in cement manufacturing. As a result, less energy is used and less $CO_2$ is released during the manufacturing of cement. At the cement plant PJSC "Ivano-FFrankivsk Cement," the problem of partially substituting finely ground limestone for Portland cement clinker in the production of market-oriented cements of type CEM II has been resolved. The following lists the results of the physical and mechanical test indexes for the high early strength CEM II/A-LLL 42.5 R certified Portland limestone cement manufactured by PJSC "Ivano Frankivsk Cements." A more thorough synergistic effect is promoted by finely scattered limestone in Portland composite cements containing slag. It is proven that the manufacturing of prefabricated and monolithic reinforced concrete benefits technologically, environmentally, and economically from the rapid-hardening of blended Portland cements with limestone powder [6].

Eshmaiel Ganjian, et. al., (2019), A variety of materials are utilized throughout the manufacturing process in addition to cement to improve the mechanical and physical qualities of Cement Composite Boards (CCB). The effectiveness of limestone powder as a cement alternative has been examined in this work. Flexural strength tests were conducted on specimens produced from five different mixes containing varying percentages of limestone powder. 15%, 20%, 5%, and 0% of the cement in these mixtures was substituted with limestone powder. Based on the results, the cement composite board's maximum flexural strength was achieved at 5% and 10% substitution of limestone powder. According to the BS EN 12467 standard, the ideal combination found in this inquiry certifies as Class 1 [7].

Satish D. (2018) investigated how concrete behaved when limestone powder was used in place of cement. He came to the conclusion that limestone powder might replace up to 10% of the cement in concrete without affecting its strength. The necessary split tensile strength can be attained by substituting 10% of the cement with powdered limestone. When Portland cement is mixed with limestone filler, the cement's fineness increases. This increase in fineness causes the cement to hydrate more quickly, hastening the development of early strength. By lowering the production of Portland cement and $CO_2$ emissions, the use of limestone powder in cement and concrete has positive effects on the economy and ecology. In comparison to Portland cement, it appears that limestone has no effect on the amount of water needed, based on the standard consistency results. Furthermore, a large amount of water is needed to compensate for the rise in fine particle levels [8].

## 3. Constituent Materials and Experiments

### 3.1. Cement

The type of Portland cement (Type 42.5 N) that was used in the trials was made in Zliten, Libya, at the Zliten Cement Factory in accordance with Libyan regulations (No. 340/2009); Figure (2) illustrates this type of cement.

Figure (2) shows the (XRF) chemical analyzing results of Portland cement used in the present research and Table (3) listed the chemical (XRF) analyzing results for Ordinary Portland Cement (OPC). Table (4) listed the physical requirements for ordinary Portland cement [9], and Figure (3) shows the used X-ray Fluorescence (XRF) analyzer.

**Fig. 2:** Sample of Portland Cement (Zliten Cement Factory, Libya).

**Table 3:** Chemical (XRF) Analyzing Results for Ordinary Portland Cement (OPC).

| No. | Component | Contents (mass %) |
|---|---|---|
| 1 | Ca | 74.2 |
| 2 | Si | 11.7 |
| 3 | Fe | 6.19 |
| 4 | Al | 3.41 |
| 5 | S | 2.30 |
| 6 | K | 0.717 |
| 7 | Ti | 0.598 |
| 8 | Cl | 0.460 |
| 9 | P | 0.148 |
| 10 | Ni | 0.114 |
| 11 | Co | 0.0647 |
| 12 | Cu | 0.0502 |
| 13 | Zn | 0.0341 |
| 14 | Cd | 0.0036 |
| 15 | Br | 0.0027 |
| 16 | U | 0.0001 |

**Table 4:** Physical Requirements for Ordinary Portland Cement (OPC) [9].

| Property | Content Max. |
|---|---|
| Finebess | 225 m³/kg |
| Soundness | 8.0 % |
| Sulphide Sulphur (s) | 1.5 |
| Setting Time | |
| a) Initial setting time not less than | 30 min. |
| b) Final setting time not more than | 600 min. |

| | |
|---|---|
| Compressive Strength | |
| a) 72& 1 h not less than | 16 MPa |
| b) 168 f2 not less than | 22 MPa |
| c) 672 f4 not less than | 33 MPa |

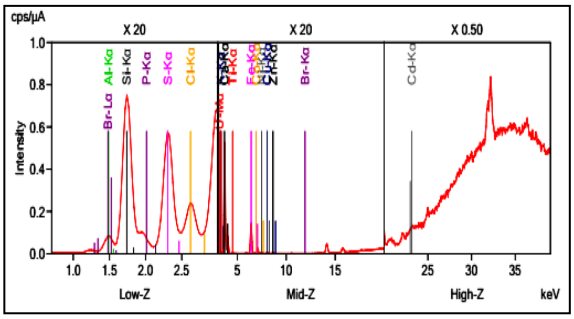


**Fig. 3:** XRF Results of Portland Cement.

**Fig. 4:** X-Ray Fluorescence (XRF) Analyzer (Sebha University, Sciences Faculty, Mansour).

### 3.2 Cement Mortar Mixing Water

Table (5) listed the contents of mineral water used to hardened the ordinary Portland cement [10].

**Table 5:** The Content of Mineral Water [10].

| Element or Variable | Content Max. |
|---|---|
| Sodium (Na) | 52.200 % |
| Calcium (Ca) | 04.008 % |
| Magnesium (Mg) | 02.400 % |
| Bicarbonates | 24.400 % |
| Chlorides (Cl) | 12.270 % |
| Sulfur (S) | 09.500 % |
| Total Dissolved Salts (T. D. S.) | 100 |
| pH | 7.3 |

### 3.3. Al-Jufra Limestone (JLS) Analysis

Table (6) and (7) listed the X-ray diffraction (XRD) and X-ray Fluorescence (XRF) chemical analyzing results of (SLS) used in the present research respectively. Figure (5) shows a sample of Soukanah Limestone (SLS) used in the experimental work of the present research.

**Fig. 5:** Sample of (SLS) Used in the Experimental Work of the Present Work.

**Table 6:** Chemical (XRD) Analyzing Results for (JLS).

| Mineral Name | Compound Name | Chemical Formula | Quantity (%) |
|---|---|---|---|
| Calcite | Calcium Carbonate | CaCO3 | 95 |
| Halite | Sodium Chloride | NaCl | 2 |
| Quartz | Silicon Oxide | SiO2 | 3 |

**Table 7:** Chemical (XRF) Analyzing Results for (SLS).

| No. | Component | Contents (Mass %) |
|---|---|---|
| 1 | Ca | 33.1 |
| 2 | Si | 26.6 |
| 3 | Fe | 19.3 |
| 4 | Al | 12.5 |
| 5 | K | 2.64 |
| 6 | Cl | 2.24 |
| 7 | Ti | 2.21 |
| 8 | S | 0.916 |
| 9 | Ni | 0.228 |
| 10 | Co | 0.111 |
| 11 | Cu | 0.0806 |
| 12 | Zn | 0.0671 |
| 13 | U | 0.0402 |
| 14 | Pb | 0.0303 |
| 15 | Cd | 0.0115 |
| 16 | Br | 0.0063 |

### 3.4 Cement Mortar Mixing Sand

Table (8) listed the (XRF) chemical analyzing results of local sand used in the present research. Figure (6) shows a sample of the local sand used in the experimental work of the present research.

**Fig. 6:** Sample of the Local Sand.

### 3.5. Experimental Specimens Preparation

Three by nine samples were prepared as part of the experimental program. The first sample included zero percent (SLS), and the subsequent samples contained cement material replacement in the amounts of five, ten, fifteen, twenty, thirty, thirty, and forty percent (SLS). Table (8) displays the mix specifications required to make cement mortar samples, which include cement, SLS, sand, and water, for each percentage of SLS replacement. After being submerged in fresh water for 28 days, the weight of each hardened cement mortar was recorded in Table (8). To calculate the average of the data, three types (SLS%) were created for each specimen (M1, M2, M3, M4, M5, M6, M7, M8, and M9). As seen in Figure (7), all samples were manufactured in the shape of a cylinder, measuring 47 mm in length and 60 mm in diameter. The PVC samples utilized in the current study to create cement mortar-hardened samples are depicted in Figure (8). The prepared samples of hardened cement mortar with varying SLS percentages are displayed in Figure (9).

**Table 8:** The Mix Specification to Prepare a Cement Mortar for each (SLS) Replacement Percentage.

| No. | Mix Code | (SLS) Ratio (%) | Cement Ratio (%) | Cement Mass (g) | Sand Mass (g) | (SLS) Mass (g) | C/W Ratio | Water Mass (g) |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | M1A | 00 | 100 | 138.00 | 138.00 | 552.00 | 552.00 | 00.00 | | 0.5 | 70.00 | 70.00 |
| 2 | M1B | 00 | 100 | 138.00 | +2% | 552.00 | +2% | 00.00 | 00.00 | 0.5 | 70.00 | +2% |
| 3 | M1C | 00 | 100 | 138.00 | 140.00 | 552.00 | 554.00 | 00.00 | | 0.5 | 70.00 | 72.00 |
| 4 | M2A | 05 | 095 | 131.10 | 131.10 | 552.00 | 552.00 | 07.00 | 07.00 | 0.5 | 65.55 | 65.55 |
| 5 | M2B | 05 | 095 | 131.10 | +2% | 552.00 | +2% | 07.00 | +2% | 0.5 | 65.55 | +2% |
| 6 | M2C | 05 | 095 | 131.10 | 133.10 | 552.00 | 554.00 | 07.00 | 09.00 | 0.5 | 65.55 | 67.55 |
| 7 | M3A | 10 | 090 | 124.20 | 124.20 | 552.00 | 552.00 | 13.80 | 13.80 | 0.5 | 61.10 | 61.10 |
| 8 | M3B | 10 | 090 | 124.20 | +2% | 552.00 | +2% | 13.80 | +2% | 0.5 | 61.10 | +2% |
| 9 | M3C | 10 | 090 | 124.20 | 126.20 | 552.00 | 554.00 | 13.80 | 15.80 | 0.5 | 61.10 | 63.10 |
| 10 | M4A | 15 | 085 | 117.30 | 117.30 | 552.00 | 552.00 | 20.70 | 20.70 | 0.5 | 58.65 | 58.65 |
| 11 | M4B | 15 | 085 | 117.30 | +2% | 552.00 | +2% | 20.70 | +2% | 0.5 | 58.65 | +2% |
| 12 | M4C | 15 | 085 | 117.30 | 119.30 | 552.00 | 554.00 | 20.70 | 33.70 | 0.5 | 58.65 | 60.65 |
| 13 | M5A | 20 | 080 | 110.40 | 110.40 | 552.00 | 552.00 | 27.60 | 27.60 | 0.5 | 55.20 | 55.20 |
| 14 | M5B | 20 | 080 | 110.40 | +2% | 552.00 | +2% | 27.60 | +2% | 0.5 | 55.20 | +2% |
| 15 | M5C | 20 | 080 | 110.40 | 112.40 | 552.00 | 554.00 | 27.60 | 29.60 | 0.5 | 55.20 | 57.20 |
| 16 | M6A | 25 | 075 | 103.50 | 103.50 | 552.00 | 552.00 | 34.50 | 34.50 | 0.5 | 51.75 | 51.75 |
| 17 | M6B | 25 | 075 | 103.50 | +2% | 552.00 | +2% | 34.50 | +2% | 0.5 | 51.75 | +2% |
| 18 | M6C | 25 | 075 | 103.50 | 105.50 | 552.00 | 554.00 | 34.50 | 36.50 | 0.5 | 51.75 | 52.75 |
| 19 | M7A | 30 | 070 | 096.60 | 096.60 | 552.00 | 552.00 | 41.40 | 124.20 | 0.5 | 48.30 | 48.30 |
| 20 | M7B | 30 | 070 | 096.60 | +2% | 552.00 | +2% | 41.40 | +2% | 0.5 | 48.30 | +2% |
| 21 | M7C | 30 | 070 | 096.60 | 098.60 | 552.00 | 554.00 | 41.40 | 126.68 | 0.5 | 48.30 | 50.30 |
| 22 | M8A | 35 | 065 | 089.70 | 089.70 | 552.00 | 552.00 | 48.30 | 41.30 | 0.5 | 44.85 | 44.85 |
| 23 | M8B | 35 | 065 | 89.70 | +2% | 552.00 | +2% | 48.30 | +2% | 0.5 | 44.85 | +2% |
| 24 | M8C | 35 | 065 | 089.70 | 091.70 | 552.00 | 554.00 | 48.30 | 43.30 | 0.5 | 44.85 | 46.85 |
| 25 | M9A | 40 | 060 | 082.80 | 082.80 | 552.00 | 552.00 | 55.20 | 55.20 | 0.5 | 41.40 | 41.40 |
| 26 | M9B | 40 | 060 | 082.80 | +2% | 552.00 | +2% | 55.20 | +2% | 0.5 | 41.40 | +2% |
| 27 | M9C | 40 | 060 | 082.80 | 084.80 | 552.00 | 554.00 | 55.20 | 57.20 | 0.5 | 41.40 | 43.40 |

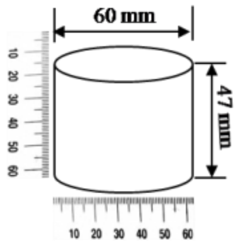


**Fig. 7:** Dimensions of Cylindrical PVC Specimen.

**Fig. 8:** PVC Specimens to Prepare Hardened Cement Mortar

### 3.6. Gravimetric Determination of Water Moisture in Cement Mortar

In concrete, water exists in three different states: unbound water held by capillarity, water that is absorbed and held by surface forces, and chemically bound water. The best technique for measuring moisture should be able to quantify the amounts of each of these three phases, but this is a challenging undertaking due to the uneven distribution of moisture in concrete and the variation in moisture distribution over time [11]. Gravimetric techniques involve weighing samples after they have been dried in an oven to ascertain the water content, which includes absorbed and chemically bound water. Infrared lamps can also be used as a heat source by automatic moisture analyzers. By comparing the weight loss of hardened concrete slices or particular parts to the initial weight of the sample, this technique calculates the amount of water lost. The results can be stated in two ways: by volume, which is the difference between the volume of water and the entire volume of the concrete sample, or by weight, which is the difference between the mass of water present and the dry weight of the concrete sample [12]. The moisture content in terms of mass water per unit volume of concrete ($W$) can be expressed
by the equation:

$$W = \frac{W_{wet} - W_{dry}}{V_{dry}} = \frac{W_{wet} - W_{dry}}{W_{dry}} \cdot \rho_{dry} \quad [13]$$

Where, $W_{wet}$ is the wet wieght, $W_{dry}$ is the dry wieght, $V_{dry}$ is the dry volume and $\rho$ is the appreant density of the concrete defined as $\rho_{dry} = W_{dry} / V_{dry}$ [13]. Table (9) shows the results of calculated apparent density and water moisture content of the prepared hardened cement mortar samples.

**Table 9:** The Calculated Apparent Density and Water Moisture Content of the Prepared Hardened Cement Mortar Samples.

| No. | Mix Code | Early Mass $W_{dry}$ (g) | Volume $V_{dry}$ (cm³) | Appar- ent Density (g/cm³) | Late Mass $W_{wet}$. (g) | Moisture Content (g/cm³) |
|---|---|---|---|---|---|---|
| 1 | M1A | 734 | 382.484 | 1.919 | 762 | 0.0705 |
| 2 | M1B | 748 | 382.484 | 1.956 | 775 | 0.0681 |
| 3 | M1C | 745 | 382.484 | 1.948 | 774 | 0.0730 |
| 4 | M2A | 735 | 382.484 | 1.922 | 757 | 0.0558 |
| 5 | M2B | 743 | 382.484 | 1.942 | 765 | 0.0558 |
| 6 | M2C | 739 | 382.484 | 1.932 | 762 | 0.0583 |
| 7 | M3A | 709 | 382.484 | 1.854 | 733 | 0.0327 |
| 8 | M3B | 719 | 382.484 | 1.880 | 745 | 0.0656 |
| 9 | M3C | 729 | 382.484 | 1.906 | 753 | 0.0607 |
| 10 | M4A | 754 | 382.484 | 1.971 | 765 | 0.0283 |
| 11 | M4B | 756 | 382.484 | 1.976 | 768 | 0.0309 |
| 12 | M4C | 769 | 382.484 | 2.010 | 782 | 0.0334 |
| 13 | M5A | 745 | 382.484 | 1.948 | 770 | 0.0632 |
| 14 | M5B | 755 | 382.484 | 1.974 | 779 | 0.0608 |
| 15 | M5C | 750 | 382.484 | 1.961 | 774 | 0.0608 |
| 16 | M6A | 760 | 382.484 | 1.987 | 769 | 0.0232 |
| 17 | M6B | 751 | 382.484 | 1.963 | 758 | 0.0181 |
| 18 | M6C | 751 | 382.484 | 1.963 | 759 | 0.0207 |
| 19 | M7A | 731 | 382.484 | 1.911 | 762 | 0.0777 |
| 20 | M7B | 725 | 382.484 | 1.895 | 762 | 0.0920 |
| 21 | M7C | 742 | 382.484 | 1.940 | 776 | 0.0850 |
| 22 | M8A | 755 | 382.484 | 1.974 | 777 | 0.0559 |
| 23 | M8B | 748 | 382.484 | 1.956 | 769 | 0.0534 |
| 24 | M8C | 760 | 382.484 | 1.987 | 784 | 0.0306 |
| 25 | M9A | 755 | 382.484 | 1.974 | 767 | 0.0309 |
| 26 | M9B | 746 | 382.484 | 1.950 | 759 | 0.0334 |
| 27 | M9C | 748 | 382.484 | 1.940 | 760 | 0.0306 |

**Fig. 9:** The Prepared Hardened Cement Mortar Samples with Various (SLS %).

### 3.9. Results of Hardened Cement Mortar Failure Load and Compressive Strength

Table (10) listed the results of hardened cement mortar failure load and compressive strength, the hardened cement mortar samples ready for compression test are shown in Figure (9), and the machine used for compression test shown in Figure (10), and Figure (11) showing the relationship between (SLS %) incorporated in cement mortar and the averages of the compressive strength.

**Table 10:** Results of Hardened Cement Mortar Failure Load and Compressive Strength.

| No. | Mix Code | Surface Area (mm²) | Failure Load (kN) | Compressive Strength (MPa) | Compressive Strength Average (MPa) |
|---|---|---|---|---|---|
| 1 | M1A | 4778.36 | 31.3 | 09.606 | |
| 2 | M1B | 4778.36 | 35.4 | 08.810 | 9.543 |
| 3 | M1C | 4778.36 | 26.8 | 10.213 | |
| 4 | M2A | 4778.36 | 35.3 | 07.387 | |
| 5 | M2B | 4778.36 | 51.5 | 09.891 | 9.352 |
| 6 | M2C | 4778.36 | 33.1 | 10.037 | |
| 7 | M3A | 4778.36 | 25.6 | 09.632 | |
| 8 | M3B | 4778.36 | 38.3 | 09.885 | 9.331 |
| 9 | M3C | 4778.36 | 24.0 | 08.476 | |
| 10 | M4A | 4778.36 | 44.6 | 07.387 | |
| 11 | M4B | 4778.36 | 31.0 | 10.778 | 8.364 |
| 12 | M4C | 4778.36 | 22.3 | 06.927 | |
| 13 | M5A | 4778.36 | 34.6 | 07.241 | |
| 14 | M5B | 4778.36 | 32.9 | 06.885 | 7.534 |
| 15 | M5C | 4778.36 | 40.5 | 08.476 | |
| 16 | M6A | 4778.36 | 18.7 | 09.334 | |
| 17 | M6B | 4778.36 | 35.3 | 06.487 | 6.830 |
| 18 | M6C | 4778.36 | 32.4 | 04.669 | |
| 19 | M7A | 4778.36 | 45.9 | 06.550 | |
| 20 | M7B | 4778.36 | 42.1 | 07.408 | 6.522 |
| 21 | M7C | 4778.36 | 48.8 | 05.609 | |
| 22 | M8A | 4778.36 | 19.6 | 05.357 | |
| 23 | M8B | 4778.36 | 25.9 | 08.015 | 6.132 |
| 24 | M8C | 4778.36 | 21.0 | 05.023 | |
| 25 | M9A | 4778.36 | 18.5 | 03.913 | |
| 26 | M9B | 4778.36 | 23.1 | 07.387 | 6.027 |
| 27 | M9C | 4778.36 | 17.7 | 06.780 | |

**Fig. 10:** Compression Test Machine Used in the Present Work.

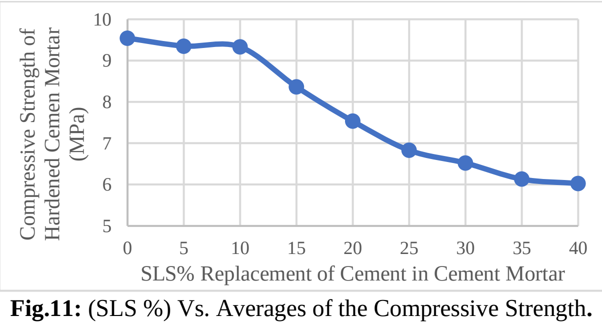


**Fig.11:** (SLS %) Vs. Averages of the Compressive Strength.

## 4. Experiments Results Discussion

The XRD analysis of the limestone samples from the Soukanah area that were investigated shows that the limestone is clean and primarily made up of calcite. Physical investigation revealed that the moisture content ranges between 0.0181-0.0920 g/cm³ and the apparent density is between 1.854 and 2.010 g/cm³. The XRF data show that 95.0% of the pure and dominant composition of limestone is calcium carbonate. According to the compression strength data, the hardened cement mortar's compressive strength and its (SLS%) concentration are inversely correlated. When the solid-state solidification (SLS) in the cured cement mortar was only 5%, the highest compressive strength value was 9.352 MPa. The hardened cement mortar's compressive strength declined gradually as the SLS concentration was increased. The hardened cement mortar's compressive strength decreased between 0% and 5% (SLS) concentration by approximately 2.0% and between 0% and 10% (SLS) concentration by approximately 2.220%. Additionally, the hardened cement mortar's compressive strength decreased between 0% and 40% (SLS) concentration by approximately 37.00%. Compressive strength is increasing at SLS 5%.

## 5. Conclusions

The density and moisture content of Soukanah limestone (SLS) were assessed. The chemical analysis was conducted using XRD and XRF techniques. The primary compounds found in SLS were calcium carbonate ($CaCO_3$), which accounted for 95% of the sample, and calcium oxide (CaO), which made up around 53%. To examine its impact on the compressive strength of hardened cement mortar, SLS was employed at different weight percentages (5, 10, 15, 20, 25, 30, 35, and 40). Because there were fewer actively hydrating elements present, the compression test findings showed that the higher limestone concentration decreased the long-term compressive strength. In comparison to cement mortars without any (SLS)% wt., cement mortars made by substituting up to 5% and 10% of cement with (SLS) demonstrated almost equal strength after 28 days.

## 5. The recommended Future Scope of Work

The effect of partial replacement of sand with Soukanah limestone (SLS) in cement mortar is highly recommended to studied.

## References


[1]- R P S Group, (2024). Reducing Embodied Carbon in Cement and Concrete Through Public Procurement in Ireland, Department of Enterprise, Trade and Employment (DETE), Ireland, IE000748 F01.

[2]- Santosh Pattar, et. al., (2022). Study on Concrete Partial Replacement of Cement with Limestone Powder, Department of Civil Eng., Visvesvaraya Technical University, Jnana Sangama, Machhe, Belgavm, Kranataka, 590014, India.

[3]- N. Hammou1, A.Zaoui, and M. Ferhat, (2019), "Polytypism in Calcium Oxide compound: mechanical and dynamical evidence of structural stability", Département de Génie Physique, (LPMF). Faculté des Sciences. Université des Sciences et de la Technologie d'Oran, Mohamed Boudiaf. Oran, Algeria, Version of Record: https://www.sciencedirect.com/science/article/pii/S0925838819336709.

[4]- Hassan Bakheet, (2023). Arab Advisory Council for Mining, Petroleum and Basic Natural Resources, Union of Geologists, Arab Gateway for Natural Resources, elmonier@hotmail.comhttp://kenanaonline.com/users/hasan/posts/62047.

[5]- Portland Cement Association (PCA), (2002). Masonry Information Mortar Cement: Product Data Sheet, 5420 Old Orchard Road Skokie, IL 60077-1083, Voice: 847.966.6200, Fax: 847.966.9781,Internet: www.cement.org.

[6]- Kropyvnytska T., et. al., (2021), Effect of Limestone Powder on the Properties of Blended Portland Cements, Department of building production, Ivano - Frankivsk National Technical University of Oil and Gas, Open Journal of Theory and Building Practice, Vol. 3, No. 1.

[7]- Eshmaiel Ganjian, et. al., (2019), Effect of Limestone Powder on Mechanical Properties of Cement Composite Board, Coventry University, Department of the Built Environment, Faculty of Engineering & Computing, Sir John Laing Building, Coventry, CV1 5FB, International inorganic - Bonded Fibre Composites Conference.

[8]- Satish D., (2018), Study on Behaviour of Concrete by Replacing of Cement by Lime Stone Powder, Department of Civil Engineering New Horizon College of Engineering, Bengaluru satishdeosur@gmail.com, International Journal of Advanced in

Management, Technology and Engineering Sciences, ISSN NO : 2249-7455.

[9]- Eethar Thanon Dawood and Marwa Saadi Mahmood, (2021). Production of Sustainable Concrete Brick Units Using Nano-Silica, Northern Technical University Technical engineering College Building & Construction Eng., Journal Pre-proof, Elsevier, DOI: 10.1016/j.cscm.2021.e00498.

[10]- [10] Francis Cayanan, et. al., (2023). A Review of the Effect of Mixing Water Quality on Concrete, International Conference on Geosynthetics and Environmental Engineering, DOI: 10.1007/978-981-99-4229-9_12.

[11]- Tao Luo, et. al., (2021). Early-Age Hydration Reaction and Strength Formation Mechanism of Solid Waste Silica Fume Modified Concrete, Molecules, 26, 5663. https://doi.org/10.3390/molecules26185663.

[12]- Lubna Mohammed Abd, et. al., (2020). Early-Age Hydration Reaction and Strength Formation Mechanism of Solid Waste Silica Fume Modified Concrete, 1 Shaanxi Key Laboratory of Safety and Durability of Concrete Structures, Xijing University, Molecules, 26, 5663. https://doi.org/10.3390/molecules26185663.

[13]- Fengbin Zhou, (2023). Moisture Diffusion Coefficient of Concrete under Different Conditions, School of Civil Engineering, Chongqing University, Chongqing 400045, China, Buildings, 13(10), 2421; https://doi.org/10.3390/buildings13102421.