



## Assessment of Shiranish and Pilaspi Limestone for Concrete Aggregates, Shaqlawa Area, Iraqi Kurdistan Region

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### Abstract

Limestone of Shiranish and Pila Spi formations were evaluated as concrete aggregates through this study. For this purpose two outcrops had been selected; the first outcrop is Pila Spi Formation at Pirmam Anticline, and the second outcrop is Shiranish Formation at Safin Anticline. Both outcrops are located in the High Folded Zone, between Erbil and Shaqlawa cities.

Chemical analysis for the studied samples shows that the limestone of Shiranish Formation has more calcite proportion, while the limestone of Pila Spi Formation is dolomitic. This was supported by the X-ray analysis and staining process by Alizarin Red S. To assess the studied limestone for concrete aggregate, the samples have been crushed and sieved into two grades, 4-30 mm (coarse aggregate) and finer than 4 mm (fine aggregate). The coarse portion is used instead of pebble and the fine portion is used instead of sand in concrete mixture. Eight briquettes with dimensions of 15 cm<sup>3</sup> for each sample were formed. Two ratios of cement: fine aggregates: coarse aggregates were tested; 1: 1.5: 3 and 1: 2: 4 respectively. These raw materials were mixed with water in two ratios; 1:0.5 and 1: 0.75 for cement: water ratio respectively.

The compressive strength tests show that the concrete prepared from Shiranish limestone aggregate give best results when compared with that prepared from Pila Spi limestone aggregate. These results proved that the Pila Spi limestone is suitable for using as aggregate in manufacturing concrete masonry only after twenty eight days of soaking in water. While Shiranish limestone is suitable for using as an aggregate in manufacturing concrete masonry after seven and twenty eight days soaking in water, as well as aggregate in manufacturing concrete foundation, column and roof after twenty eight days soaking in water. In addition to that, other concrete briquettes were formed from both formations, after soaking the limestone aggregates in water for 24 hours and showed bad results in the term of consistency.

### Introduction

Since concrete is the most important part in structural construction, an aggregate with good strength is required for such purposes. Concrete is made up of aggregate, cement and water. Through this combination of materials, three-quarter of the mix is governed by aggregate (Smith and Collis, 2001). The aggregate itself is categorized as fine and coarse aggregate.

Concrete is a hardened building material created by combining a chemically inert mineral aggregate (usually sand, gravel, or crushed stone), a binder (natural or synthetic cement), chemical additive, and water (Whitney, 2008). There are three factors having a huge effect on concrete workability: a water-cement ratio,

aggregate-cement ratio and water quantity, which are inter-related. The water quantity depends on aggregate type, particle size distribution, shape and texture of grains and quantity of fines (Ćurčić *et al.*, 2010).

Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids (Amsterdam, 2008). Conventional concrete aggregates currently used in the Iraqi Kurdistan Region are gravel and sand which are usually collected from deposits found in the bends of major rivers, and these are mostly igneous and metamorphic rocks with chert and jasper. These stones are usually very hard and typically round because they have been broken away from the hills and then water currents literally “polish” them as they roll down the river. Crushed limestone (limestone aggregate) has several important advantages over river gravel as an aggregate for concrete. First, crushed limestone concrete will have more strength and lighter in weight. This strength advantage comes from the fact that cements bonds tighter to limestone than to smooth gravel (Jomaa'h, 2012). Second, because crushed limestone is free from silica materials, therefore will avoid the alkali-aggregate reactivity problem (Bates, 1969). Crushed limestone concrete also has a lower thermal coefficient of expansion than gravel concrete. This means that slabs poured with limestone concrete will expand and contract less than gravel concrete for a given change in temperature (Neville, 1996).

One of the disadvantages of using conventional pebble and sand as aggregate in concrete industry is alkali-aggregate reactivity problem (cancer of concrete). The hardening of cement is a chemical process that produces heat and liberates alkalis, particularly the hydroxides of calcium, sodium, and potassium. There is a group of siliceous materials which, if present in aggregate, react chemically with the alkalis released by the cement. These materials include chiefly opaline shale, opaline and chalcedonic chert, and siliceous cryptocrystalline volcanic rocks. Apparently sodium and potassium, released during setting of the cement, react with the above mentioned unstable materials to produce alkalic silica gel. This gel absorbs water from the cement paste and develops expansive stresses that may exceed the tensile strength of the concrete and cause cracking or blister-like (Bates, 1969; Farny and Kosmatka, 1997).

**Aim of the study:**

The main aim of this study is to assess the crushed limestone taken from the Shiranish and Pila Spi formations as a concrete aggregate.

**Geological setting:**

In this study, two channel samples (represent the whole formation deposit) were taken from the limestone of two selected outcrops. The first was taken from Pila Spi Formation, at Pirmam anticline, near Pirmam area at Lat. 36° 22' 2.23" N and Long. 44° 11' 39.85" E. The second was taken from Shiranish Formation at Safin Anticline, near Hujran village at Lat. 36° 25' 7.04" N and Long. 44° 16' 19.71" E (Fig. 1-A). Structurally and tectonically, both studied outcrops are situated on the Southwestern limb of Safin anticline in the High Folded Zone, which is a part of unstable shelf (Jassim and Buday, 2006) (Fig. 1-B).

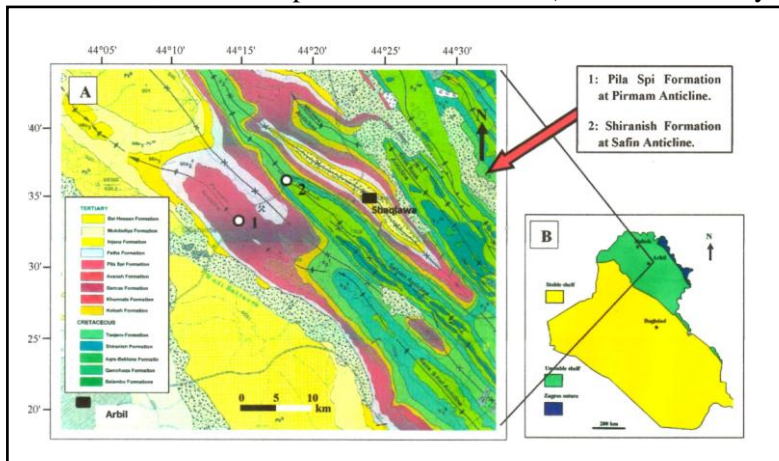


Figure-1: (A) Tectonic map of Iraq (Jassim & Buday, 2006), (B) Geological map of the area show the studied outcrops (State Establishment of Geological Survey and Mining of Iraq, 2000).

Stratigraphically, many formations are represented in the area. Since this study is related with Shiranish and Pila Spi Formations, the lithology of these formations in studied area was described briefly in the following, according to (Bellen *et al.*, 1959, Sissakian and Youkhana, 1979):

**1- Shiranish Formation (Upper Campanian-Lower Maastrichtian):**

The formation was first defined by Henson in 1940 from High Folded Zone of northern Iraq near the village of Shiranish Islam, northeast of Zakho (Bellen *et al.*, 1959). Lithologically, it consists of two parts. The lower part consists of limestones which are occasionally clayey or marly, white to light grey in colour, well bedded. Some of the limestones are fossiliferous; others are glauconitic with some pyrite crystals. The upper part consists of blue and bluish grey marls and papery shales; locally fragmented into chips.

**2- Pila Spi Formation (Upper Eocene):**

The formation was first described by Lees in 1930 from the Pila Spi of the southeastern margins of the High Folded Zone and redefined by Wetzel in 1947 (Bellen *et al.*, 1959). The formation consists mainly of limestones which are crystalline, dolomitic, clayey and chalky dolomites. The colour is white, creamy, light grey and yellowish white, well bedded. Occasionally these limestones are fossiliferous. The uppermost beds contain iron oxides and chert concretions up to few centimeters in size. In the vicinity of Salahaddin (northeast of Erbil), some of the limestone horizons are highly dolomitized. The lowermost part of this formation consists of conglomerate, which marks the unconformable contact with the underlying Gercus Formation.

**Field work:**

A field trip was carried out to the study area, which is located between Erbil and Shaqlawa cities. Due to huge reserve of limestone, two channel samples from each locality was selected; the first channel sample was collected from the Pila Spi Formation at Pirmam anticline, and the second channel sample was collected from the lower part of Shiranish Formation near Hujran village (Fig. 2). About fifty kilograms limestone in the form of boulders was collected from each mentioned locations.

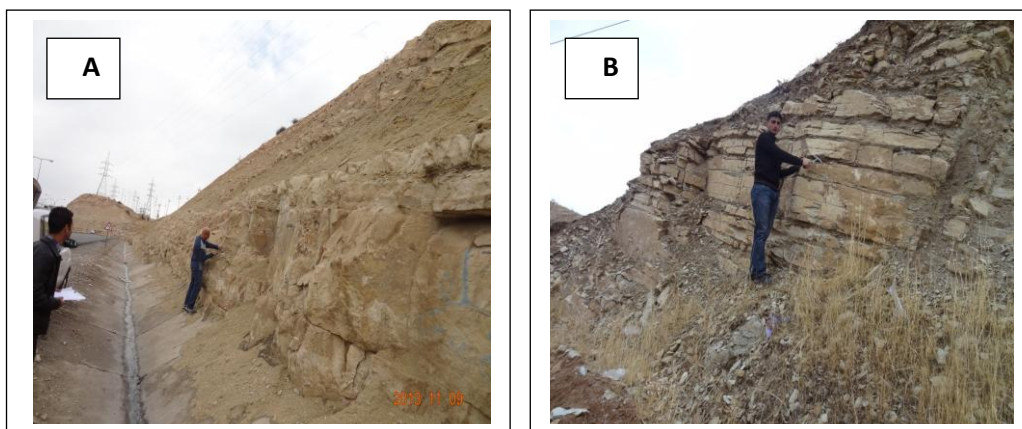


Figure-2: The studied formations; (A) Pila Spi Formation at Pirmam anticline, (B) Shiranish Formation at Safin Anticline.

**Laboratory works:**

The following procedures were carried out on the studied limestone samples during laboratory works:

**A. Chemical analysis:**

Due to the important role of the calcium and magnesium ratio in the concrete industry, the chemical analysis for the studied samples was carried out for both studied samples. The X-ray fluorescence (XRF) technique in the laboratories of the Iraqi Geological Survey-Baghdad was used for this purpose.

### **B. X-ray diffraction:**

X-ray technique was used to determining the proportion of calcite and dolomite in the studied limestone samples. This technique was carried out in the laboratories of the Iraqi Geological Survey-Baghdad.

### **C. Staining:**

Rock slice from each limestone samples was prepared, and stained with Alizarin Red S solution to distinguishing the limestone with dolomitic limestone according to Friedman (1959).

### **D. Crushing:**

The studied limestone samples had been crushed by a crushing machine and sieved into two grades; 4-30 mm (coarse aggregate) and finer than 4 mm (fine aggregate) (Fig. 3). The coarse portion is used instead of pebble and the fine portion is used instead of sand in concrete mixture.

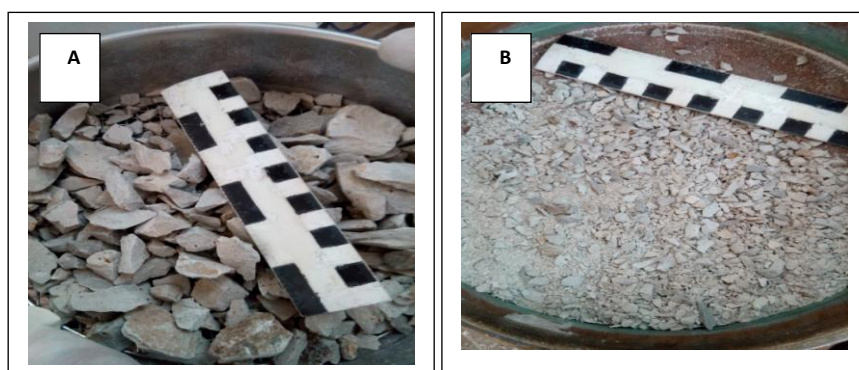


Figure-3: The grain size distribution of studied samples; (A) coarse aggregates (4-30 mm), and (B) fine aggregates (finer than 4 mm).

### **E. Mixing and forming:**

The Iraqi standard specifications 1077 (1987) depended on the ratio 1: 2: 4 for cement to fine aggregates to coarse aggregates respectively, with the proportion of cement to water 1: 0.5. In this study, two types of mixture had been used to prepare concrete briquettes. The first mixture (Mixture I) at a ratio 1: 1.5: 3 and the second mixture (Mixture II) at a ratio 1: 2: 4 for cement to fine aggregates to coarse aggregates respectively (Table 1). These raw materials were mixed in a homogenized form before adding the water, because the distribution of fine and coarse aggregates has an important role on the coherence of the concrete paste (Kozul and Darwin, 1997). The proportions of cement and water have been used in two ratios; the first is 1: 0.5 and the second is 1: 0.75 for cement to water respectively. In addition to that, other concrete mixture was prepared after immerse the crushed limestone (fine and coarse) in water for 24 hours. In all these mixtures, the local portland cement (Almas cement Factory) was used.

Eight concrete briquettes were prepared from each studied sample, by a mold in 15 cm<sup>3</sup> dimensions (Fig. 4). Four of them were prepared with the ratio 1: 1.5: 3 and another four with the ratio 1: 2: 4 of cement: fine aggregate: coarse aggregate respectively. Two of these were prepared in the ratio 1: 0.5 for cement: water respectively and others in the ratio 1: 0.75. All briquettes were placed in the water after 24 hours from forming date and opening the mold. One of the briquettes of each sample was used to conduct the compressive strength for concrete after seven days from forming date, while another one was used to conduct the compressive strength for concrete after twenty eight days from forming date.

Table-1: Types of mixture used to prepare concrete briquettes.

| Mixture I   |   | Mixture II              |                          |
|---|---|-------------------------|--------------------------|
| cement: fine aggregate: coarse aggregate<br>1: 1.5: 3 | cement: fine aggregate: coarse aggregate<br>1: 2: 4 |                         |                          |
| cement: water<br>1: 0.5                               | cement: water<br>1: 0.75                            | cement: water<br>1: 0.5 | cement: water<br>1: 0.75 |



Figure-4: The concrete briquettes prepared from the studied limestones, in the different ratios of raw materials and water.

#### ***F. Compressive strength:***

The assessing of validity of concrete in construction industries depends essentially on the compressive strength values. Eight concrete briquettes for each studied limestone were prepared for this test. These briquettes were prepared in two different ratios of cement: fine aggregate: coarse aggregate; 1: 1.5: 3 and 1: 2: 4. As well as two ratios of cement: water was used; 1: 0.5 and 1: 0.75. Each type of the products was tested after 7 and 28 days of soaking in water. This test was carried out in the Department of Civil Engineering, College of Engineering / Salahaddin University.

#### **Results and discussion:**

The results of the chemical analysis show that the proportion of CaO in studied limestone is 53.77 % in Shiranish Formation and 47.26 % in Pila Spi Formation, while the proportion of MgO in the studied limestone is 1.10 % in Shiranish Formation and 9.42 % in Pila Spi Formation. Therefore, the CaO/MgO ratio in the Shiranish limestone is 48.88, while in Pila Spi limestone is 5.02 (Table 2). These values improve that the calcite to dolomite ratio in the Shiranish limestone is much more than that in the Pila Spi limestone, i.e. the limestone of Pila Spi Formation is dolomitic. This had evidenced by X-ray analysis (Fig. 5) and staining process with Alizarin Red S (Fig. 6). These techniques show that the Shiranish sample is poor in dolomite; therefore it stained with dark red colour. While the Pila Spi sample is dolomitic, therefore it stained with pink colour. The presence of high proportion of MgO (dolomitic limestone) in in the raw material aggregates, will affect negatively on the compressive strength results of the concrete (Mikhailova *et al.*, 2013).

Table-2: Chemical analysis of the studied limestone samples.

| wt. %                              | Shiranish Formation | Pila Spi Formation |
|------------------------------------|---------------------|--------------------|
| <b>CaO</b>                         | 53.77               | 46.26              |
| <b>SiO<sub>2</sub></b>             | 2.18                | 1.06               |
| <b>Al<sub>2</sub>O<sub>3</sub></b> | 1.41                | 1.62               |
| <b>Fe<sub>2</sub>O<sub>3</sub></b> | 0.82                | 0.63               |
| <b>MgO</b>                         | 1.10                | 13.42              |
| <b>TiO<sub>2</sub></b>             | 0.27                | 0.44               |
| <b>Na<sub>2</sub>O</b>             | 0.18                | 0.21               |
| <b>K<sub>2</sub>O</b>              | 0.16                | 0.14               |
| <b>P<sub>2</sub>O<sub>5</sub></b>  | 0.12                | 0.19               |
| <b>L.O.I.</b>                      | 39.98               | 36.03              |
| <b>CaO/MgO ratio</b>               | 48.88               | 3.45               |

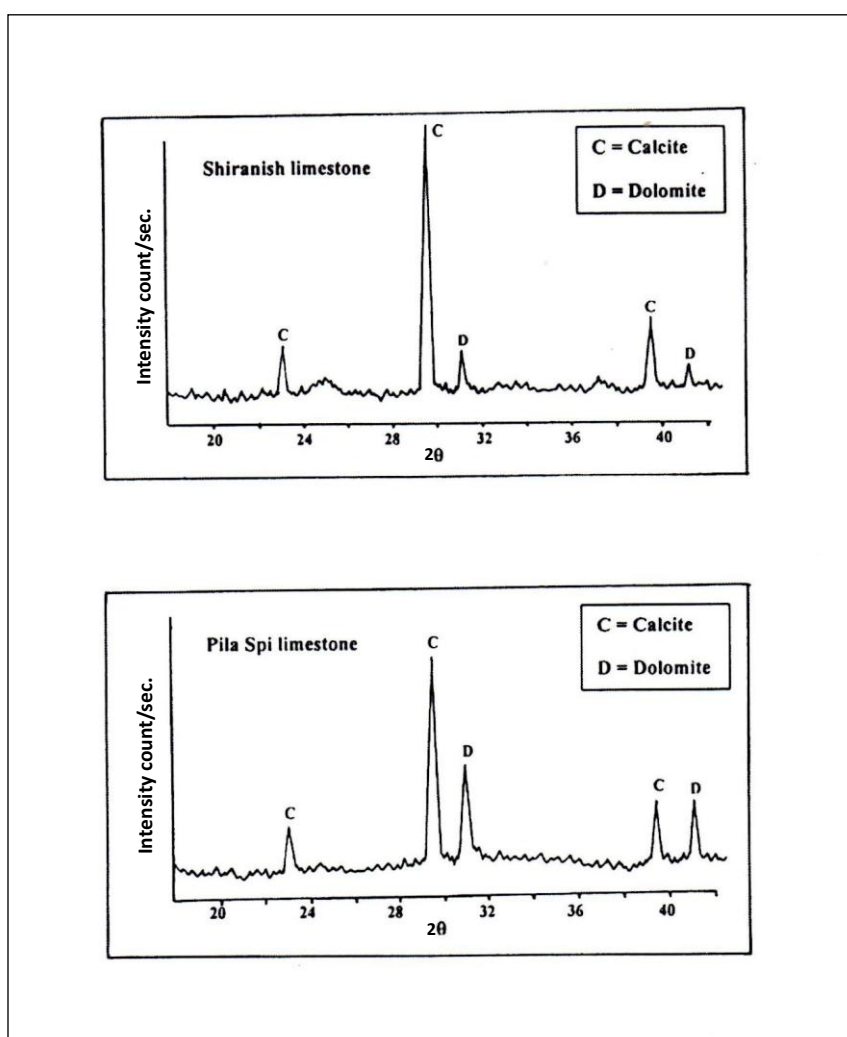


Figure-5: X-ray diffractograms for the studied limestone.

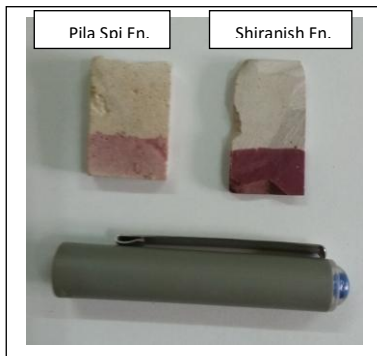


Figure-6: Staining the studied samples with Alizarin Red S.

The joint blister had been doesn't noted in the all studied briquettes after seven and twenty eight days soaking in water. The results of compressive strength tests for the concrete briquettes had been compared with ASTM C90 (1970) and Iraqi standard specifications 1077 (1987). According to these specifications the compressive strength value required for concrete masonry must be between 9 to 25 Mpa, and for concrete foundation, column and roof must be more than 25 Mpa. The results show that the Pila Spi limestone is suitable for using as aggregate in manufacturing concrete masonry only after twenty eight days soaking in water, with cement: water ratio 1: 0.75 in mixture I and 1: 0.5 in mixture II. While Shiranish limestone is suitable for using as aggregate in manufacturing concrete masonry after seven and twenty eight days soaking in water, with cement: water ratios 1: 0.75 in mixture I; as well as 1: 0.5 and 1: 0.75 in mixture II. It had been noted also that Shiranish limestone can be used as aggregate in manufacturing concrete foundation, column and roof after twenty eight days soaking in water, with cement: water ratio 1: 0.75 in mixture I; and 1: 0.75 in mixture II. Therefore, in mixture I, the briquettes prepared in the ratio 1: 1.5: 3 for the cement: fine aggregate: coarse aggregate respectively, gives the best results with the ratio of cement: water at 1: 0.75. While in mixture II, the briquettes prepared in the ratio 1: 2: 4 for the cement: fine aggregate: coarse aggregate respectively, gives the best results with the ratio of cement: water at 1: 0.5 (Table 3 and Fig. 7). In addition to that, it has been noted that the concrete briquettes soaked for twenty eight days in water give a best compressive strength values than that soaked for seven days, due to complete reactions between the components of the concrete past. As well as, there are a directly relationship between the cement and water proportions in accepted results. Whereas the proportion of cement in mixture I is relatively more than in mixture II. The results show that the concrete briquettes prepared from Shiranish limestone gives a higher compressive strength values when compared with that prepared from Pila Spi limestone. According to chemical analysis, X-ray diffractograms and staining process, this can be attributed to that the Pilaspi limestone is dolomitic, while Shiranish limestone is poor in magnesium oxide.

Table-3: Compressive strength values for the studied concrete briquettes.

| Sample                        | Compressive strength values in Mpa.                   |                               |   |                               |   |                               |   |       |
|-------------------------------|---|-------------------------------|---|-------------------------------|---|-------------------------------|---|-------|
|                               | Mixture I   |                               |   |                               | Mixture II  |                               |   |       |
|                               | cement: fine aggregate: coarse aggregate<br>1: 1.5: 3 |                               | cement: fine aggregate: coarse aggregate<br>1: 2: 4 |                               | cement: fine aggregate: coarse aggregate<br>1: 1.5: 3 |                               | cement: fine aggregate: coarse aggregate<br>1: 2: 4 |       |
|                               | cement: water<br>1: 0.5                               |                               | cement: water<br>1: 0.75                            |                               | cement: water<br>1: 0.5                               |                               | cement: water<br>1: 0.75                            |       |
| after 7 days soaking in water | after 28 days soaking in water                        | after 7 days soaking in water | after 28 days soaking in water                      | after 7 days soaking in water | after 28 days soaking in water                        | after 7 days soaking in water | after 28 days soaking in water                      |       |
| Shiranish limestone           | 6.93  | 8.04                          | 15.33   | 27.68                         | 16.28   | 30.46                         | 10.55   | 12.72 |
| Pila Spi limestone            | 5.22  | 6.16                          | 8.21  | 14.15                         | 7.14  | 13.21                         | 4.37  | 6.19  |

Unsuitable for using;
  Suitable for use as concrete masonry;
  Suitable for use as concrete foundation, column and roof.

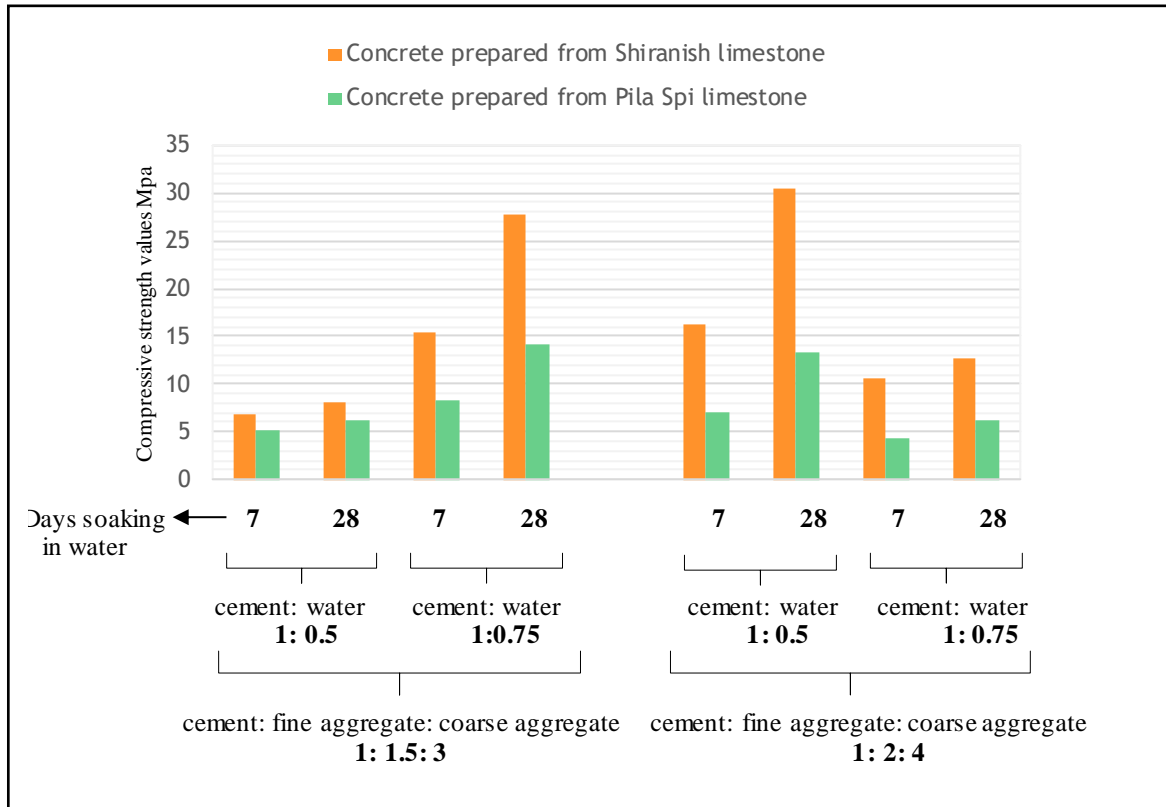


Figure-7: Compressive strength values of concrete prepared from studied limestones with respect to different ratios of cement, water, fine aggregates and coarse aggregates.

Many researches such as (Nmai *et al.*, 1999 and Ćurčić *et al.*, 2010) preferred soaking the limestone aggregates in water for 24 hours before forming the concrete mixture, due to high porosity and water absorption of limestone on the contrary of pebble and sand. During this research, other concrete briquettes were formed after soaking the limestone aggregates in water for 24 hours showed a bad result in the term of consistency. This concrete was failure during opening the mold after 24 hours from the forming process. The reason of this problem may be attributed to the saturation of limestone with water before mixing with cement and losses its ability to consistency with it.

### **Conclusions:**

The most important conclusions that have been achieved are:

- 1- Shiranish limestone is more suitable in using as concrete aggregates than Pila Spi limestone, because that the first is free from dolomite, while the last sample is dolomitic.
- 2- Two mixture types of cement: fine aggregate: coarse aggregate give a best results. The first is 1: 1.5: 3 respectively, with cement: water ratio 1: 0.75; and the second is 1: 2: 4 respectively, with cement: water ratio 1: 0.5. The second type of mixture is preferred because it is more economic in related with cement amount.
- 3- There is a direct relationship between the cement and the water proportions in accepted compressive strength results. This ratio is very important and it is related with the ratio of cement: fine aggregate: coarse aggregate.
- 4- The results of compressive strength tests for concrete briquettes after twenty eight days of soaking in water are better than that soaked for seven days.

### **Recommendations:**

- 1- Estimation the reserve of Shiranish Formation in the studied area, and study the possibility of establishing the limestone aggregate concrete factories as alternative for the conventional raw materials.
- 2- Application of the required tests on the other formations composed mainly from dolomite.

### **Acknowledgement:**

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