# The effect of Minoodasht region calcined clay of Golestan province and silica fume on the mechanical properties of concrete

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**ABSTRACT:**

**In this research, calcined clay was used as pozzolan, first the soil is heated to 700 degrees Celsius to be calcined, then it is replaced with cement with lime powder. In this research, 10 mixed designs were used in 2 ratios of w/c, 0.35 and 0.4. In each proportion of clay at 0, 10 and 20%, limestone powder at 0, 30 and 20%, respectively, and microsilica along with the combination of soil and lime at 0 and 7% by weight as powder materials were replaced by cement. . In order to check the properties of the prepared soil, XRF and XRD tests were performed on it. To investigate and analyze the mechanical properties of concrete from compressive strength tests on 10 cm cube samples at 4 ages of 3, 7, 28 and 90 days, tensile strength on cylindrical samples and flexural strength on prismatic samples at 28 years of age. Fasting was used. over the time and reaching the age of 90 days, designs containing 20% calcined clay and 20% lime Mix3 and Mix8 have more resistance in pozzolanic designs and are introduced as optimal pozzolanic designs.**

**KEY WORD:**

**calcined clay, pozzolan, compressive strength, tensile strength, bending strength**

## Introduction

Cement and concrete are essential for the infrastructure of the modern world, no other material can satisfy the ever-increasing demand for structural materials with the same low environmental impact. The wide availability and low price of cement has made it the most widely used material on earth, which with reinforced concrete includes more than half of the factory production that humans produce. This large volume of cement and concrete production includes about 5-8% of $CO_2$ emissions caused by human activity[1]. Pozzolan is a material with the combination of $Al_2O_3$ and $SiO_2$, which does not have cement value by itself, but if it is fine crystal or amorphous, it will have cement properties in the vicinity of lime water. This silicon or silicon-aluminum material reacts with calcium hydroxide caused by cement hydration in the presence of moisture and produces cement products [2]. Substituting 5 to 20% of calcined kaolin (metakaolin) instead of cement in concrere increased its compressive, tensile and bending strength, and at the replacement of 15%, the compressive strength became optimal [3]. Since the replacement of metakaolin as a part of cement improved the mechanical properties of concrete, the researchers concluded that there are three effective factors in improving the mechanical properties and durability of concrete: filler effect, acceleration of cement hydration (in high degrees) and the pozzolanic reaction of metakaolin with calcium hydroxide [4,5]. the effect of metakaolin on improving the tensile strength of concrete is greater, also, the replacement of metakaolin in concrete has increased the flexural strength of concrete compared to the control sample in low water-to-cement ratios [5]. Due to the filling effect, acceleration of hydration and pozzolanic reaction with CH in the form of C-S-H, metakaolin increases the compressive strength of concrete, reduces permeability and porosity, and improves the pore structure [6]. In more recent studies based on different percentages of metakaolin in calcined clay, it was observed that the higher the amount of metakaolin in calcined clay, the more compressive strength concrete samples made with it[7]. The results of research on 4 types of LC3 concrete that were made using two types of soil and two types of lime, 30% calcined clay and 15% limestone powder were replaced by cement and were made in two water to cement ratios of 0.475 and 0.5. It shows that their compressive, tensile and bending resistances are also high and they have performed well[8].

**Materials and methods**

The characteristics of the chemical composition of cement materials including cement, clay and lime stone powder used in this research are given in Table 1.The calcination process of clay including kaolinite occurs at a temperature between 550 and 900 degrees Celsius, which results in the production of an amorphous silica compound called metakaolin, which is an aluminosilicate pozzolan, and this reaction is shown in formula 1 [9].

$$Al_2Si_2O_5(OH)_4 \longrightarrow Al_2O_3.2SiO_2 + 2H_2O \quad (1)$$

Table1: Characteristics of chemical compounds of cement materials

| %Weight | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | $K_2O$ | $Na_2O$ | FreeCaO | IR | LOI | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cement | 20.8 | 5.2 | 3.65 | 62.1 | 1.8 | 2.5 | 0.55 | 0.3 | 1.2 | 0.3 | 1.5 | 99.9 |
| Silica fume | 93.95 | 0.9 | 0.8 | 1 | 1.25 | 0.06 | 0.25 | 0.4 | | | 1 | 99.61 |
| Clay | 57.6 | 17.7 | 5.6 | 6.3 | 3.3 | 0.03 | | | | | 9.68 | 99.67 |
| Limestone | 5.6 | | 0.05 | 51.7 | 1.4 | | | | | | 41.15 | 99.9 |

In Table 2, the specifications of each mix design are given.

Table2: Specifications of the concrete mix design made in the research

| Mix Design | w/c | Cement % | Clay % | Lime stone % | Silica Fume % | Coarse Agg (kg/m3) | Fine Agg (kg/m3) | Free Water (kg/m3) | Cement (kg/m3) | Clay (kg/m3) | Limestoe (kg/m3) | Silica Fume (kg/m3) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C0L0 | 0.35 | 100 | 0 | 0 | 0 | 744 | 1116 | 140 | 400 | 0 | 0 | 0 |
| C10L30 | 0.35 | 60 | 10 | 30 | 0 | 744 | 1116 | 140 | 240 | 40 | 120 | 0 |
| C20L20 | 0.35 | 60 | 20 | 20 | 0 | 744 | 1116 | 140 | 240 | 80 | 80 | 0 |
| C10L30SF7 | 0.35 | 55.8 | 10 | 30 | 4.2 | 744 | 1116 | 140 | 223.2 | 40 | 120 | 16.8 |
| C20L20SF7 | 0.35 | 55.8 | 20 | 20 | 4.2 | 744 | 1116 | 140 | 223.2 | 80 | 80 | 16.8 |
| C0L0 | 0.4 | 100 | 0 | 0 | 0 | 736 | 1104 | 160 | 400 | 0 | 0 | 0 |
| C10L30 | 0.4 | 60 | 10 | 30 | 0 | 736 | 1104 | 160 | 240 | 40 | 120 | 0 |
| C20L20 | 0.4 | 60 | 20 | 20 | 0 | 736 | 1104 | 160 | 240 | 80 | 80 | 0 |
| C10L30SF7 | 0.4 | 55.8 | 10 | 30 | 4.2 | 736 | 1104 | 160 | 223.2 | 40 | 120 | 16.8 |
| C20L20SF7 | 0.4 | 55.8 | 20 | 20 | 4.2 | 736 | 1104 | 160 | 223.2 | 80 | 80 | 16.8 |

**Results and Discussion**

With increasing age, the compressive strength of the samples has increased. The reason for this is that with increasing age, the hydration between cement and water has increased, causing the reduction of lime water in concrete and the increase of silicate gel in it. The compressive strength of the pozzolanic samples is lower than that of the control concrete, the reason for this is the incompleteness of the pozzolanic reactions and their diluting properties (not having enough calcium hydroxide for the pozzolanic reaction). But with the passage of time and the samples reaching the age of 28 days and 90 days, this lack of resistance has been compensated to a large extent and the resistance of the design samples has reached close to the resistance of the control samples, which indicates the beginning of pozzolanic reactions of calcined clay after the initial ages.The tensile strength values have decreased with the increase in the ratio of water to cement materials from 0.35 to 0.4 at the age of 28 days, which is due to the increase in the thickness of the surface transition zone (ITZ) following the increase in the amount of water consumed in concrete. to be As a result, the increase in the thickness of the surface transfer zone in concrete causes an increase in the porosity of the concrete and a decrease in the tensile strength of the samples.Concretes made with calcined clay have higher ductility than normal concretes, and for this reason, they have accepted more cracks during bending tests and have endured a relatively good load, but in the control designs, due to brittleness after reaching the critical load With the first microcracks, the test beam was destroyed.

**Conclusion**

1- The mechanical properties of all designs improve over time, which is more noticeable in the designs containing pozzolan and causes these designs to become denser than the control design.

2- The 28-day compressive strength of designs was lower than the control design's compressive strength, but with the passage of time and reaching the age of 90 days, a large part of This reduction has been compensated.

3- The values of compressive strength in designs in which calcined clay, limestone powder and microsilica were used at the same time were very suitable and after 90 days, it obtained the highest values of compressive strength in pozzolanic designs.

4- samples reaching the age of 90 days, the designs containing 20% calcined clay and 20% lime have the highest resistance in pozzolanic designs and the pozzolanic reactions in them are more complete and are introduced as optimal pozzolanic designs.

5- In the tensile strength test, the process of gaining strength is the same as the compressive strength test, and the optimal amount of calcined clay is 20%, and the highest amount of tensile strength for pozzolanic designs is assigned to the design containing 20% calcined clay and 7% microsilica.

6- In the modulus of rupture test, from the point of view of the amount of applied load, the designs had a trend similar to the compressive and tensile strength, but in a range very close to the control design, but from the point of view of the amount of spring created, they acted completely opposite to the resistance behavior.

7- According to the load capacity of designs including soil, which is in a range close to the control designs and at the same time, the flexibility is higher than the control design, it can be concluded that concretes made with calcined clay have higher ductility than normal concretes.

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