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# Production of Lime from the Limestone of Isparta Region, Turkey

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Lime is a material that has been widely used over the ages. The existence of lime has been proven by the fact that the earth crust contains 3.5-4 % limestone and magnesium. Different types of limestone are present in various formations on the earth crust. They vary in their colour, chemical composition, texture, crystal type and hardness. Some special properties are expected from the lime according to the purpose of usage in industry. In this study, the properties of the limestone sample provided from Isparta distinct are examined, in order to study the possibility of lime production.

**Key Words: Limestone, Lime, Isparta, Turkey.**

## INTRODUCTION

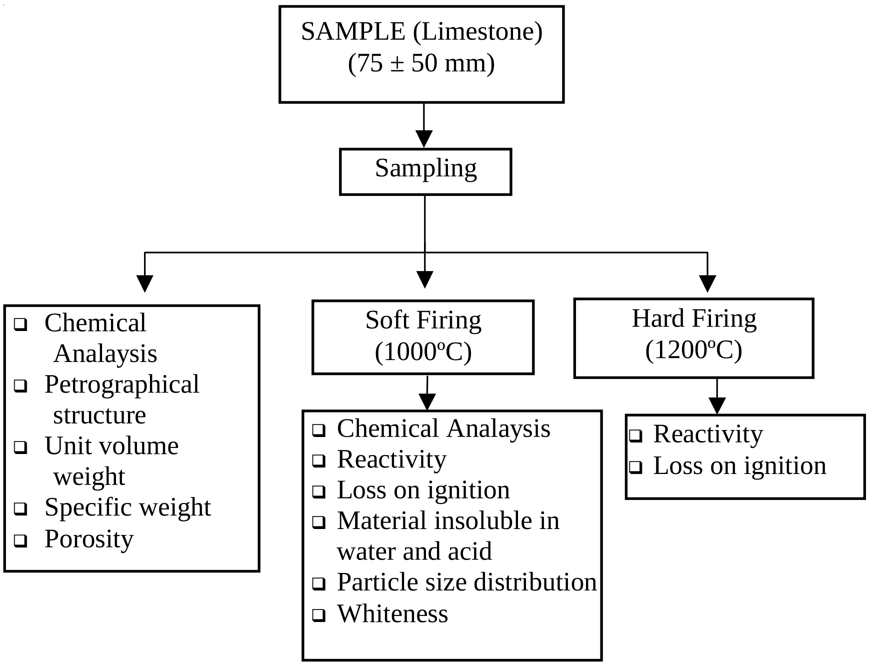
Lime is a material is known for its versatile use since antique ages. It has been known that limestone was used in the construction of the Pyramids in ancient Egypt and in the construction of various buildings in old Roman era. An old text on the use of lime in construction mortar has been found in a book titled De Architectura written by a Roman engineer Marcus Polo in the era of Emperor Augustus. With the fast development of chemistry and steel industries at the turn of the century, vast amount of lime has started to be used. With this development, world lime production[1] reached to 128 million tons in 2005. The use of lime in industries, agriculture and environmental sectors is a result of the commonness of the lime producing plants, close vicinity of the places it is used and the development in its production[2].

Lime (CaO) is produced through the calcinations of limestone containing calcium carbonate at 900-1000ºC. Limestone is composed of the mineral calcite (calcium carbonate) and/or the mineral dolomite (calcium and magnesium carbonate) along with small amounts of other minerals. There are three distinct types of limestone which are defined by their magnesium carbonate ($MgCO_3$) contents: (i) dolomitic limestone consisting of 35-46 % magnesium carbonate, (ii) magnesian limestone consisting of 5-35 % magnesium carbonate and (iii) high calcium limestone containing less than 5 % magnesium carbonate. For this reason, properties and the places of usage of the lime to be obtained from these lime stones are different.

In this study, the properties of the limestone sample provided from Isparta are examined, in order to study the possibility of lime production.

## EXPERIMENTAL

A limestone sample of 75 ± 50 mm in size was tested to see whether it was adequate for producing lime and to see the quality of the lime produced under laboratory conditions. The tests conducted are shown in **Scheme-I**.




**Scheme-I** Schematic display of the tests conducted

The analyses were conducted for studying the physical and chemical properties of limestone. The studies were conducted to determine the properties of CaO, which was obtained by exposing lime stone to soft and hard firing.

Both the tests were conducted to determine the properties of lime stone and CaO obtained as a result of firing and the results obtained from these tests are given below. All the required examinations have been conducted on the quality of the lime obtained from the sample, in compliance with the standards, fields it is going to be used and firing methods.

**Tests for lime firing:** Pieces of 70-75 mm in size were exposed to heat regime given in Figs. 1 and 2 by applying soft and hard firing in a controlled laboratory kiln (Vecstar).

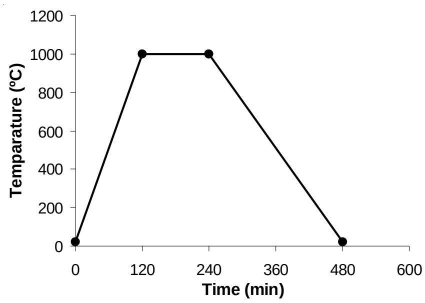



Fig. 1. Temperature-time graphic in soft firing

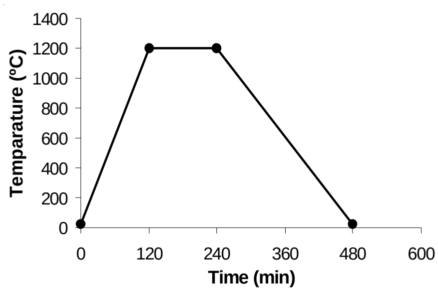



Fig. 2. Temperature-time graphic in hard firing

**Soft firing:** This test was conducted at calcinations temperature of 1000ºC. The type of lime aimed is the one which is soft fired and shows high reactivity.

**Hard firing:** At a test conducted at calcinations temperature of 1200ºC, a kind of hard fired lime was aimed.

The examination of the pieces of lime obtained at the end of the experiments some cracks and fragmentation were observed. It was determined that there occurred no contraction in pieces of soft fired lime but as expected there was a certain degree of contraction in hard firing.

The quality of lime depends on the method of firing as well as the limestone. In industries, conventional vertical kilns are used for the production of soft, medium, hard and hard fired lime. For the production of soft, highly reactive lime, Maerz type regenerative kilns are recommended. Although investment costs for Maerz kiln are high, but it is a kind of kiln preferred in Europe because its fuel expenses (850 kcal/kg lime) are very low. Contrary to the vertical kilns used in Europe, rotary kilns are used in the US the lime produced in these kilns are of high quality, but fuel consumption is high (1350-1500 kcal/kg lime) and dust separating (collecting) units are big and costly.

## RESULTS AND DISCUSSION

### Limestone analysis

**Petrographical structure:** Microscopic examination of thin fractions of the sample revealed the existence of calcareous particles of 300-400 mm in size and that the particles were bound to each other by calcareous cement. The examination showed that the limestone sample has a crystalline structure. Coarse calcite crystalline particles were also present in the form of seams in the limestone sample, though small in amount. Since limestone sample has a fine crystalline structure, it can be said that it could be fired easily in a lime kiln and would not undergo decrepitating compared to coarse crystalline limestone. The reactions of the lime to be obtained would be of good quality.

**Unit volume weight, Specific weight, porosity:** As a result of analysis the following were determined:

| | |
|---|---|
| Unit volume weight (g/cm$^3$) | 2.61 |
| Water absorption (by weight) (%) | 1.41 |
| Specific weight (g/cm$^3$) | 2.71 |
| Porosity (%) | 3.69 |

Unit volume weight bigger than 2.55 g/cm$^3$ suggests that this limestone has got a dense texture and that it is the kind of limestone that can be referred in lime production. Besides, it is possible that it would render a positive effect in that the porosity in the lime stone allows $CO_2$, which is formed during firing, to leave the structure and that it prevents the lime being fired from contracting. The reactivity of the limes produced from high porosity limestone is high and that have small contraction and that the particle sizes of the hydrates obtained from this kind of lime are small and thus their specific surface areas are large is an important advantage.

**Chemical analysis of limestone:** The results of the analyses aimed at determining the chemical structure of the sample limestone investigated are given below. CaO: 54.054 %, MgO: 0.085 %, $SiO_2$: 0.059 %, $Al_2O_3$: 0.002 %, $Fe_2O_3$: 0.003 %, S: 0.017 %, Loss on ignition: 43.018 %.

As can be seen from the analysis of the limestone, percentage ratios of the impurities ($SiO_2$, $Fe_2O_3$, $Al_2O_3$) present in the stone are quite low. The ratio of $Fe_2O_3$ being very low will affect positively the whiteness of the lime and slaked lime to be produced from this stone. Since the ratio of MgO is less than 1 per cent, the type of lime to be produced from this stone will fall into the class of lime with high level of calcium. This kind of lime is more advantageous than limes containing MgO in terms of fields of usage and for marketing.

## Properties of lime

**Chemical analysis:** Chemical analysis of the soft fired lime is presented below.

| | | | |
|---|---|---|---|
| CaO (%) | : 94.40 | $Fe_2O_3$ (%) | : 0.05 |
| MgO (%) | : 1.40 | S (%) | : 0.03 |
| $SiO_2$ (%) | : 1.00 | Loss on ignition (%) | : 2.85 |
| $Al_2O_3$ (%) | : 0.33 | Reactive CaO (%) | : 91.20 |

Chemical analyses explicitly show that it is the sort of lime with high calcium and low impurity. It falls into the class of high calcium[3,4] stated in

TS 30 and TS 4022. It is not possible to produce lime with 0 % loss on ignition in both laboratory and industrial kilns. The reasons for this are that partial re-carbonization cannot be prevented in calcinations process which is realized in a $CO_2$-rich atmosphere and that in big chunks of lime there remains calcium carbonate core that are not undergone calcinations. For this reason, it is very difficult or even impossible to produce lime with less than 1-1.5 % loss on ignition in conventional vertical kilns.

By applying fast sugar analysis, the ratio of reactive CaO was found to be 91.2 %. This figure shows that the lime produced is of good quality.

**Reactivity tests:** Results of the reactivity test conducted are displayed in Fig. 3. The time needed for reaching reaction temperature of 60ºC is $t_{60}$ = 1.5 min and this value shows that the lime is very reactive. This reactivity stems from firing the stone in a homogenous way and at low temperature under laboratory conditions, the positive contribution of the properties of the stones itself should not be overlooked.

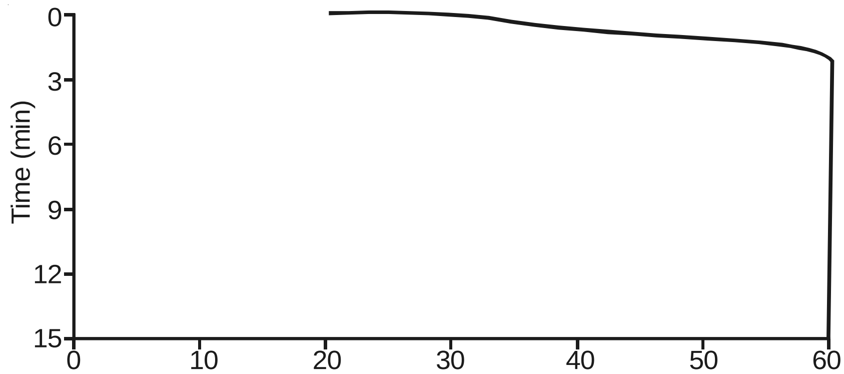



Fig. 3. Results of soft fired reactive lime

It is difficult to produce reactive lime at this degree in conventional vertical kilns. But in parallel flowing, reactive kilns such as Maerz and rotary kilns, it is possible to produce soft-fired, high reactivity lime.

Since it will show similarity with that of soft fired- lime, the analysis for hard fired lime (at 1200ºC) was not conducted (Fig. 4). It is possible to produce lazy lime (lime with low reactivity) at higher temperatures and/or with longer calcinations period. In practice, it is easy to produce lime with low reactivity in vertical kilns. But it is difficult to produce lime with high reactivity.

The loss of calcinations for hard fired lime was determined as 1.65 %. As can be seen from this analysis, the ratio of carbonate which underwent calcinations in the lime lesser that that of soft fired lime, for this reason the ratio of the reactive CaO is higher. The ratio of reactivity for this lime was found as 95.95 %.

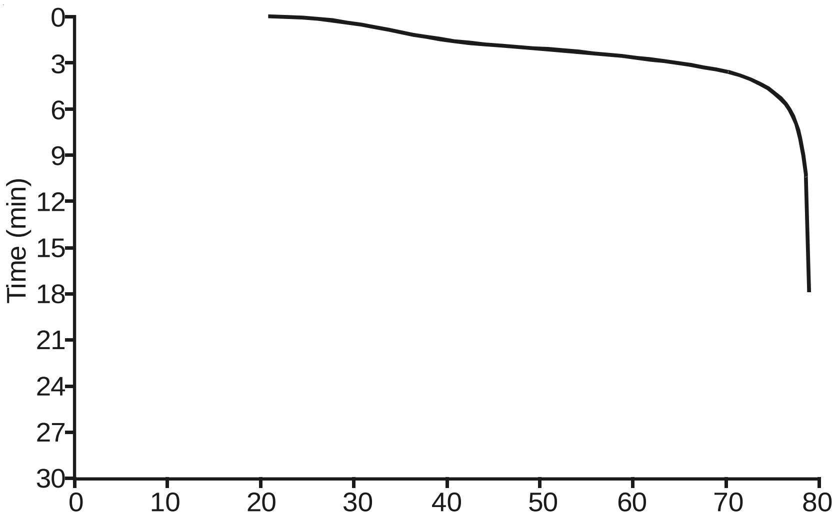


Fig. 4. Results of reactivity tests for hard fired lime

**Ratios of material insoluble in water and acid:** It was determined that ratios of material that do not dissolved in water and acid for soft fired lime were found as 3.34 and 0.77 %, respectively. The amount of material that does not dissolve in water generally stems from unfired calcium carbonate. The fact that amount of material that do not dissolve in acid is rather low is an indication that the lime is pure.

**Analysis for slaked lime and specific surface area:** The results of analysis for slaked lime particle size are given in Table-1 and Fig. 5. The analyses data reveals that average particle size for slaked lime was 4.1 micron, 50 % of the material was below 3.8 micron, and 99.84 % of the material was below 53 micron. Specific surface area was calculated as 1.766 $m^2$/mL or 3.532 $m^2$/g (unit volume weight was taken as 0.5 g/$cm^3$). These figures suggest that slaked powder or dough lime will be of good quality. Specific surface area desired in slaked powder lime is around 1.5-2 $m^2$/g.

**Whiteness test:** The results of whiteness test for unslaked lime are as follows. L: 90.34 (lightness), A: -2.07 (greenness), B: 2.98 (yellowness).

It is clear from the results of whiteness tests, unslaked lime produced in laboratory show a high degree of whiteness and it has a good quality in terms of whiteness. It should be noted here that the lime to be fired in industrial level would not be so white due to the impurities coming through fuel and inhomogeneous firing. But as long as clean limestone is used in industrial lime production, the whiteness of the lime to be produced will be high.

TABLE-1
PARTICLE SIZE ANALYSIS FOR SLAKED LIME

| Channel number (*ι*) | Particle diameter (μm) | Cumulative undersize (%) | Cumulative oversize (%) |
|---|---|---|---|
| 1 | 1.05 | 0.00 | 100.00 |
| 11 | 1.23 | 0.53 | 99.47 |
| 21 | 1.43 | 1.84 | 98.16 |
| 31 | 1.67 | 4.92 | 95.08 |
| 41 | 1.95 | 11.04 | 88.96 |
| 51 | 2.27 | 19.29 | 80.71 |
| 61 | 2.65 | 26.97 | 73.03 |
| 71 | 3.09 | 35.64 | 64.36 |
| 81 | 3.61 | 46.01 | 53.99 |
| 91 | 4.21 | 57.52 | 42.48 |
| 101 | 4.91 | 68.47 | 31.53 |
| 111 | 5.73 | 76.26 | 23.74 |
| 121 | 6.69 | 81.43 | 18.57 |
| 131 | 7.81 | 85.05 | 14.95 |
| 141 | 9.11 | 88.51 | 11.49 |
| 151 | 10.63 | 91.42 | 8.58 |
| 161 | 12.40 | 93.67 | 6.33 |
| 171 | 14.47 | 96.32 | 3.68 |
| 181 | 16.88 | 96.52 | 3.48 |
| 191 | 19.69 | 97.39 | 2.61 |
| 201 | 22.98 | 98.06 | 1.94 |
| 211 | 26.81 | 98.61 | 1.39 |
| 221 | 31.28 | 99.07 | 0.93 |
| 231 | 36.50 | 99.51 | 0.49 |
| 241 | 42.59 | 99.57 | 0.43 |
| 251 | 49.69 | 99.75 | 0.25 |

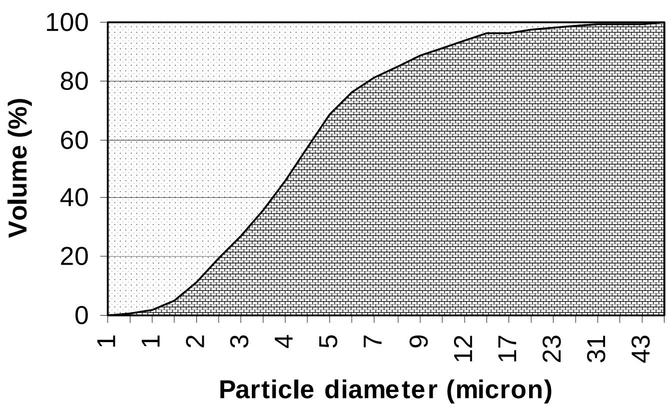



Fig. 5. Particle size analysis for slaked lime

## Conclusion

The following conclusions were driven as a result of evaluating the tests and analyses, (i) lime stone coming from Isparta region has thin crystals, has no cracks and has adequate porosity. With this structure, it can be fired without any problem and give high quality lime, (ii) analyses of the limestone and lime suggest that impurities in this limestone are very low (below 1%). The ratio of MgO in the limestone being below 1 % suggests that the lime to be produced from this stone will be of high quality, (iii) the tests conducted on the sorts of lime produced from limestone calcinated at temperatures of 1000ºC and 1200ºC suggested that (a) the ratio of reactive CaO is high ((higher than 91.2 %), (b) reactivity of lime is high (the reason why it is preferred in many sectors), (c) lime at the level of whiteness that will be preferred at the market will be produced, (d) besides, the fact that the amount of material insoluble in water and acid is low and that slaked lime has got very fine particle size are the features that increase the quality of the lime to be produced.

As a result, it is suggested that the limestone from Isparta region is an appropriate material for lime production in terms of both physical and chemical properties.

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