Effect of limestone powder on the uniaxial compressive behaviour of cement-treated sand

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Abstract

A study has been conducted to investigate the compressional behaviour of cemented sand containing limestone powder as filler material. Cylindrical specimens were made by using sand, limestone powder and high early strength cement with a specific ratio of water to cement (W/C) and cement to sand (C/S); and varying ratios of limestone powder to cement (L/C). The influences of the filler materials on the compressive strength and setting times of the mix were investigated. Results have indicated that limestone powder as a filler material has relatively less effect on the uniaxial compressive strength, whereas, setting time is highly influenced by the type of filler material.

Key Words: Cement, Sand, Limestone powder, Compressive strength

1. Introduction

Soils are used as foundation material from ancient times. Soil is natural occurring cheapest material that can be used to support the foundation and also as fill material. The unconsolidated mineral grains resulted from the disintegration of rocks results in the formation of soil. The properties of foundation soil can be improved by using ground modification techniques such as compaction, addition of cement etc. Problematic soils have been ignored for a long time in favour of quality soils with reduced technical difficulties and lower construction costs. Alternative areas for construction have become important during the last decades, due to non- availability of better quality soils for construction. These limitations can be resolved by improving the engineering properties of soils. The use of cement-treated sand to improve the foundation characteristic is rapidly increasing because of its relative ease of use. A mixture of sand with cement is used to improve soil engineering characteristics. This technique is used in the coastal and offshore area [1]. However, the effects of filler materials used in cement-treated sand are not well understood.

Soil improvement is defined as a method in which engineering properties of soil is improved by some additives. The soil grain size distribution influences the behaviour of structures supporting on it. The engineering behaviour of soil can be changed by removing selected fractions from it. Generally, the soil improvements techniques are relatively economical as compared with the removal technique of stabilization of weak soils. The knowledge of the characteristics of soil is important for engineering purposes, e.g., for the design of foundations, tunnels and dams. The type of stabiliser for soil improvement depends on the treated soil; for clayey soils, lime is the preferred stabiliser due to the mineral composition of the clay, while for sandy soils, cement is preferred. The use of limestone powder is not limited to soil improvement but its use in concrete can lower its cost and enhance the greenness of concrete, as the production of limestone powder needs less energy and causes less CO_2 emission than Portland cement [2].

Cementation properties in soil enhance the engineering properties. Researchers have investigated the improvement in properties of soil using cementing agent [3]. The understanding of time-dependent behaviour of such treated soils is important as it influences the behaviour of the structure supporting it. The limestone powder is used as an adulterant in the mortar by many researchers around the world. Its use can improve the durability of concrete. However, the use of limestone powder in excess results in an increase in surface area of powder that leads to increase in water demand [4]. It is observed by researchers that limestone powder can be used as filler material. It remains unhydrated even after 28 days in concrete [5]. The use of limestone powder in bricks are found to be cost-effective and it reduces the unit weight of the brick [6]. Researchers have observed that interparticle friction increases between particles with the increase in powder volume. It affects the workability of the mix that ultimately reduces the strength [7]. The properties of soil can be modified by the addition of a small quantity of cement but adding more cement may result in brittle failure of treated soil [8]. The stiffness of treated soil can be enhanced by the addition of cement but it reduces the strain threshold at failure.

In this paper, the uniaxial compressive behaviour of cement-treated sand with varying ratios of limestone powder, as wells as the effect of filler materials on setting times were investigated.

2. Experimental Program

2.1 Materials

Sand, limestone powder and high early strength cement were used to make the test specimens. The oven-dried sand that had passed through a 5 mm sieve was used The sand was classified as Poorly graded (uniformly graded) with coefficients of curvature and uniformity as 1.07 and 2.50, respectively. The sand classification was performed as per the Unified soil classification system [9]. The water absorption of sand was 1.32%. The particle densities of the materials used are given in Table 1.

Table 1: Particle densities of materials

Materials	Density (g/cm^3)
Sand	2.63
Cement	3.16
Limestone	2.70

The workability and viscosity of the mix are increased by using limestone powder. In mix design, the exisiting moisture of limestione powder was ignored. A gradation of limestone powder and sand is shown in Fig. 1.

2.2 Mix proportions

The test variables were W/C as 150%, C/S as 30%; and L/C as 100%, 130%, 150%, 170% and 190% by weight. The L/C ratios were varied to study the effect of limestone powder content on the behaviour of cement-treated sand. These ratios were decided after trial tests to get the optimum results with a workable mix as lower W/C results in relatively harsh mixes. The limestone powder was first mixed with sand; then cement was mixed. Finally, water was added to the mix. The specimens were cured by covering with wet cloths.

2.3 Specimens and testing methods

2.3.1 Unconfined compression test

Effect of specimen size on compressive strength of cement-treated sand was investigated by Tariq et al. [10] and was concluded that cement-treated sand has less variation in peak strength with respect to specimen size. Cylindrical specimens having diameter of 100 and 200 mm (D) were cast. The uniaxial compression tests were performed at curing periods of 7 and 14 days. The compression test was performed with controlled loading. Transducers were used to measure the external average strain of the test specimens.

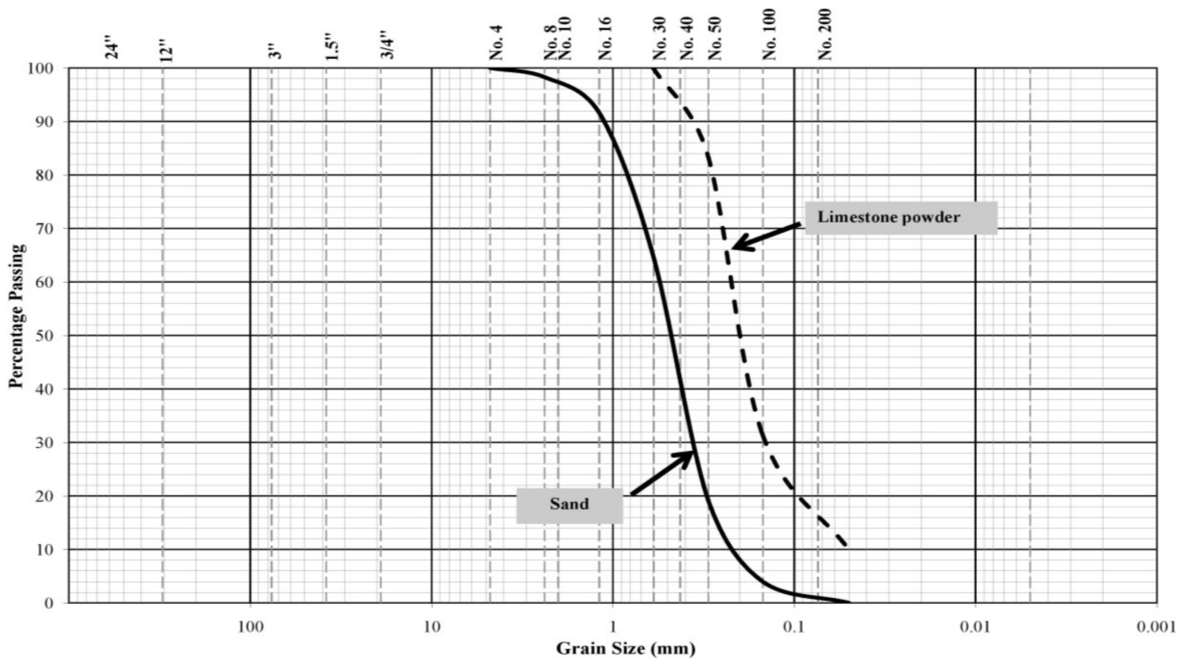

Fig. 1: Gradation analysis of limestone powder and sand

The ratios of limestone powder were varied; keeping constant water to cement ratio of 150% and cement to sand ratio as 30%. Finally, compression tests on 29 specimens were performed for specimens having varying ratios of limestone powder. In addition to that, Poisson's ratios were also measured [11] with the help of strain gauges attached to the surface of the test specimens.

2.3.2 Setting time

Vicat's apparatus was used to investigate the setting time of mixes. The ASTM standard procedures [12] were used to calculate the setting time of the mixes. The tests were performed in controlled temperature and humidity.

3. Test results and discussion

3.1 Peak stress, Strain and Young's modulus

The uniaxial compressive strength for the specimens cured for 14 days with specific ratios of W/C = 150%, C/S = 30% and varying ratios of L/C are summarised in Table 2. The development of strengths at curing time for varying ratios of L/C are shown in Fig. 2.

Table 2: Uniaxial compressive strengths (MPa) for varying ratios of L/C at 14 days

L/C (%)	Strength (MPa)
100	5.86
130	6.66
150	6.06
170	6.91
190	7.20

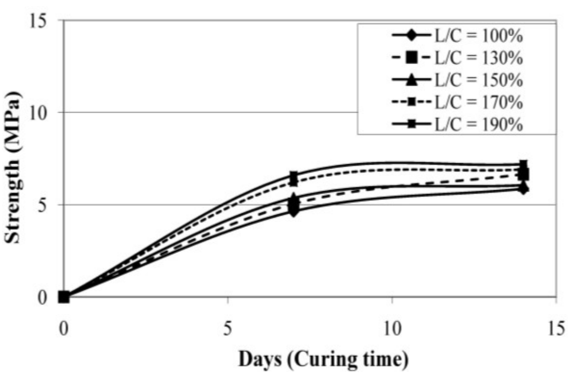

Fig. 2: Uniaxial compressive strength for varying ratios of L/C

The strain at peak stress, Poisson's ratio and Young's modulus for test specimens (14 days) was approximately 0.003(Fig. 3), 0.19 (Fig. 4) and 3.5 GPa (Fig. 5) respectively.

From the test results, an increasing trend of Young's modulus and Poisson's ratio was observed with the increase in limestone content. Limestone powder was used as filler material. Results have indicated that limestone powder results in more workable mix

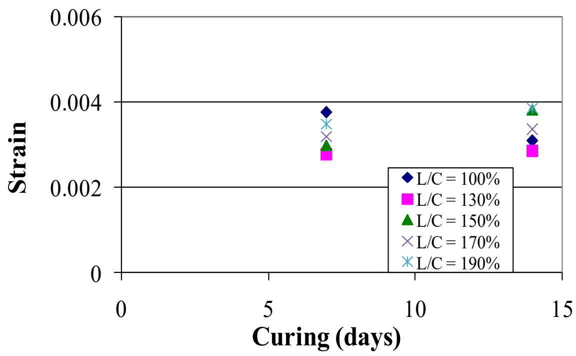

Fig. 3: Peak strain variation with Limestone powder content

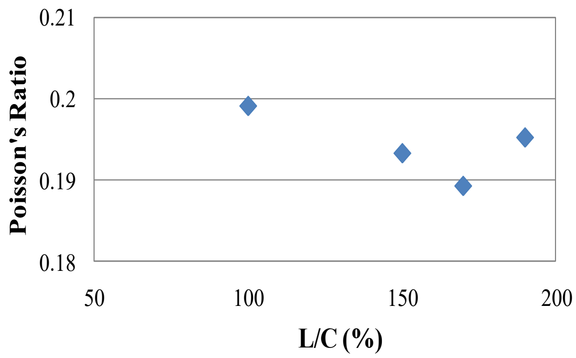

Fig. 4: Poisson's Ratio variation with Limestone powder content

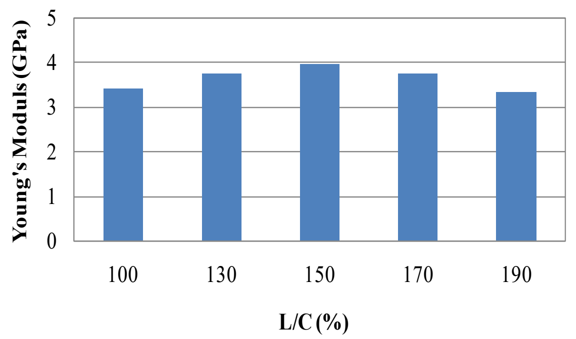

Fig. 5: Young's Modulus variation with Limestone powder content

3.2 Stress~Strain and setting time behaviour

The normalized stress-strain behaviour with the variation of L/C ratios at 14-days curing period is shown in Fig. 5. The behaviour of limestone treated cemented-sand was nonlinear at high strain levels as compared with relatively linear behaviour at a lower strain. Results have indicated that the post-peak softening mechanism depends on filler material content.

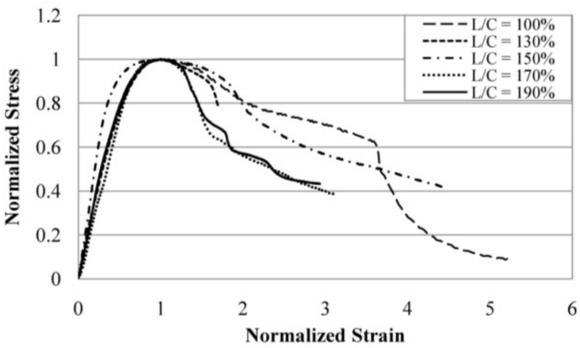

Fig. 6: Stress~Strain behaviour

The intial and final setting time decreases with the increase in limestone content (Fig. 6).

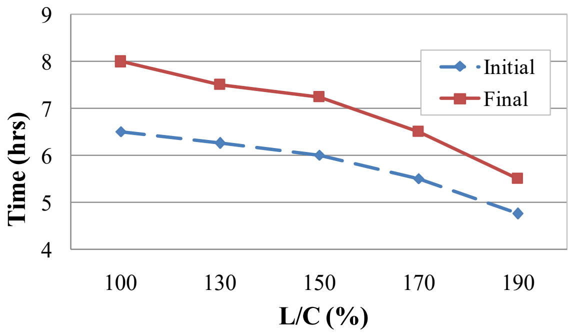

Fig. 7: Setting time variation with Limestone content

4. Conclusions

The mechanical behaviour of cement-treated sand is investigated using limestone powder as filler material. Following results are deduced from the experiments:

- Higher content of sand results in relatively harsh mixes with reduction in strength.
- The uniaxial compression strength of cement-treated sand shows variation with limestone powder content. The workability phenomena of the mix is the possible reason for such behaviour.
- The peak strain and poisson's ratio for W/C = 150% is approximately 0.003 and 0.19 respectively. With the increase of limestone content, a general increase in peak strain and poisson's ration is observed.
- The average Young's modulus for W/C = 150% is 3.5 GPa. The mixture having L/C = 150% results in optimum mix. Other mixes have resulted in slighty lower results.
- The limestone powder content has effect on the intial and final setting time of the mixes. Mixes having higher limestone conent results in decrease in intial and final setting time.
- The behaviour of cement-treated sand after peak stress changes from relatively ductile to brittle with the increase in limestone powder content.

5. References

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