Effects of Delay Time on Compaction and Strength Properties of Stabilized Granular Soil

B Siva Manikanta Kumar [1], Suresh Prasad Singh [2] and Chadarangam Sreenivasulu[3]
[1] M.Tech Student, Department of Civil Engineering, National Institute of Technology. Rourkela (217ce1426@nitrkl.ac.in)
[2]Professsor, Department of Civil Engineering, National Institute of Technology. Rourkela (spsingh@nitrkl.ac.in)
[3] M.Tech Student, Department of Civil Engineering, National Institute of Technology. Rourkela (218ce1278@nitrkl.ac.in)

Abstract. Weak and marginal soils are conventionally stabilized with chemical stabilizers like lime and cement. During construction of stabilized soil structures sometimes inevitable delays occurs between mixing the additive with the soil and compaction, which have adverse effect on the geoengineering properties of the stabilized structures. The present study emphases on the effects of delay time on compaction and strength properties of a granular soil stabilized with three different stabilizers i.e. lime, cement and slag based geopolymers. The granular soil is mixed with 2.5, 5, 7.5, 10, and 15% of lime and cement and 5,10,15% of slag based geopolymer by dry weight of the soil. The optimum moisture contents (OMC) and maximum dry densities (MDD) of these mixes were determined after delay periods of 0, 3, 6, 12, 24, 48, 72, 168 hours. As well, cylindrical specimens of size 36mm diameter and 72mm lengths were prepared for all these mixes compacted to MDD at OMC taking into the effects of delay. These specimens were cured at an average temperature of 300 C for 0, 7, and 28 days in closed secure environment for assuring the prevention of moisture loss while curing, after that the unconfined compressive strength (UCS) were determined. It is observed that from the test results the OMC and MDD of mixes are effected by the delay time and it is more understandable for cement and geopolymer binders than the lime. Similarly, delay time effects the strength of cement and geopolymer stabilized mixes more adversely than lime stabilized mixes

Keywords: Soil stabilization, Delay time, Compaction Characteristics, Strength properties

1 Introduction

When cement added to soil and the saturated sample compacted and cured results into a hard durable soil cement mixture. When the mixture of soil and cement is correctly compacted at the time of construction, resistant to deterioration due to moisture and weather and also it deformation does not happen due to heavy traffic loads. Baghdadi et.al. (1995) found that cement kiln dust (CKD) can significantly decrease the optimum moisture content and significantly increase the maximum dry density of pure kaolinite when the CKD content is less than 50%. Miller and Azad (2000) observed an increase in the optimum moisture content and a decrease in the maximum dry density when CKD was added into three types of soil with different high, medium, and low plasticity and concluded that the effect of CKD on optimum moisture content and maximum dry density is obviously a function of soil and CKD type as well as compaction method. Soil stabilization is a well-established discipline within geotechnical engineering. Cement is preferred for lowly cohesive (sandy) soils but it loses effectiveness for highly plastic soils. Cement is the most commonly used stabilizer and its popularity is due to quick strength gain and the ability to obtain desirable mechanical properties with relatively low amounts of stabilizer.

By adding lime to soils improves the workability and increased the strength of the mixtures, although strength gains are not as great as those due to addition of cement. For clayey soils, lime is generally used as a stabilizing agent because it flocculates the clay and increases the plasticity. Cementation ultimately results to slow Pozzolanic reaction. clay will be flocculated by cement due to free lime content. Both cement and lime added to the soil, the lime to ease mixing, and the cement to give strength and durability. Currently chemical stabilization of soils is most common method, stabilizers like cement and lime are used. But due to more usage of cement, it has given rise to environmental issues like dust generation, co2 emission. Geopolymer is a developing material as an alternative to cement. Aside from the environmental problems geopolymer stabilized soils were shown advanced properties to satisfy the microstructural and mechanical properties. When compared to compressive strengths of OPC specimen, light weight GGBS based geopolymer stabilized specimen has given 200-350% more strength.

Time elapses between mixing and compaction vary depending upon the construction method employed. During construction, a time lag may elapse between soil–lime mixing and compaction due to hitches or technical breaks for logistic reasons. In reviewing literature, conflicting recommendations and opinions can be found concerning the influence of delayed compaction: studies developed by the Louisiana Department of Transport in the early sixties pointed out that a delay longer than 48 h involves a lower strength of the soil–lime mixtures. Mitchell and Hooper (1961) found that a 24 hour delayed compaction reduced the dry unit weight and the long-term strength, whereas the swelling was found to increase.

2 Materials

1. Portland slag cement (PSC) PSC of Konark brand is used as a stabilizing agent. The properties of PSC has given in table 1

Table 1. Physical properties of Portland slag cement

Physical property	Value
Specific gravity	3.0
consistency of cement	33.5%
Initial setting time	2hr 38min
final setting time	9hr 45min

2. Lime - Lime (Calcium hydroxide) is of Loba chemie brand used as another chemical agent with 95% purity and placed in sealed container.

3. River Sand - River sand from Koel river is used as a base material. The properties of river sand has given in table 2

Table-2. Physical properties of River sand

Physical property	Value
Specific gravity	2.64
uniformity coefficient (Cu)	3.0
coefficient of gradation (Cc)	0.925
maximum dry unit weight (MDD)	17kN/m^3
optimum moisture content (OMC)	15.1%

4. Ground granulated blast slag - Slag used for study is blast furnace slag obtained from the Rourkela steel plants. Slag was 10mm in size initially which is grounded in a ball mill and sieved through 75 mm sieve before mixing to prepare samples. GGBS used is milky white in colour and has specific gravity of 2.82.

5. Sodium hydroxide - Laboratory grade sodium hydroxide pellets with 98% purity were used to prepare solution. Figure below shows the image of NaOH pellets

3 Methodology

Using different percentages of cement and lime (2.5%, 5%, 7.5%, 10%, 15%) mixed with sand, and 5,10,15% of slag based geopolymer using sodium hydroxide (NaOH) as an activator by dry weight of the soil, the maximum dry density and optimum moisture content are determined by using light and heavy compaction test, as per IS-2720(7, 8). The delayed compaction (3hrs, 6hrs, 12hrs, 24hrs, 48hrs,3 days and 7 days) for the samples with different percentages of cement, lime and slag based geopolymer are studied. Using the mix, samples are prepared for curing period of 0, 7 and 14 days at a constant temperature of 30 °C and UCS test is conducted as per IS-2720 (10).

4 Results and Discussion

4.1 Compaction characteristics

With increasing in lime content, maximum dry density (MDD) increased and corresponding optimum moisture content (OMC) also decreased for both the light compaction and heavy compaction test. In case of sand-lime mixture, MDD increased from 18 to 19.2 kN/m3 and OMC decreased from 17.2 to 13.1 % for light compaction as shown in fig 1 and fig 2. For heavy compaction, the MDD increased from 19.1 to 20.3 kN/m3 and OMC decreased from 16 to 11.7% as shown in fig 3 and fig 4. It has been analyzed, MDD increased by 6.29% and OMC decreased by 26.9% when lime content increased from 2.5% to 15%. In the same way, for sand-cement mix in light compaction, from the fig 5 it is observed that MDD increased by 10.49 % and OMC decreased by 19.35 % when the cement content is increased from 2.5 % to 15 %. Similarly, for heavy compaction MDD increases by 8.8 % and OMC decreases by 20% with the increase of cement content from 2.5 % to 15 % as shown in fig 6. In the same way slag based geopolymer MDD increased from 19.92 to 21.26 kN/m3 and OMC decreased from 10.81 to 8.85 % for heavy compaction and incase of light compaction MDD increased 19.27 to 20.69 kN/m3 and OMC decreased from 12.45 to 9.86 % as shown in fig 7 and fig 8.

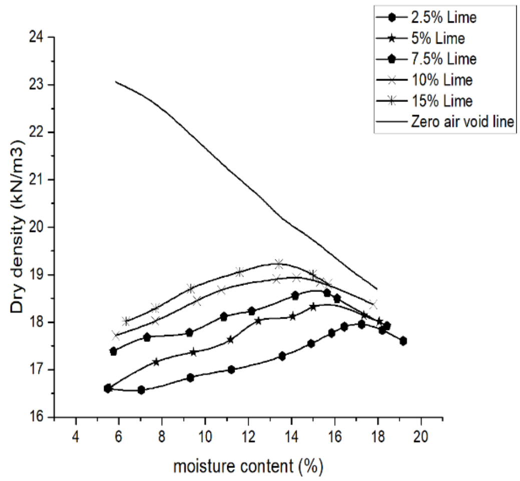


Fig 1. Light compaction curves of sand lime mixes

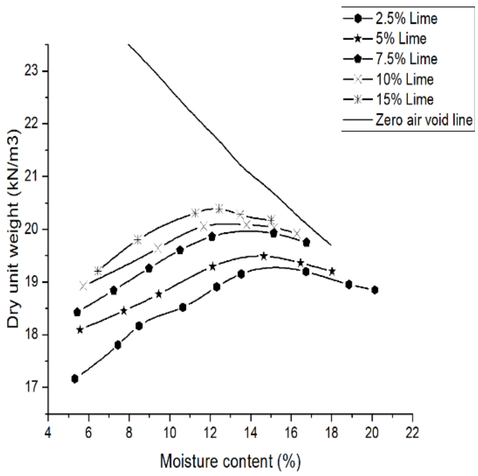


Fig 2. Heavy compaction curves of sand lime mixes

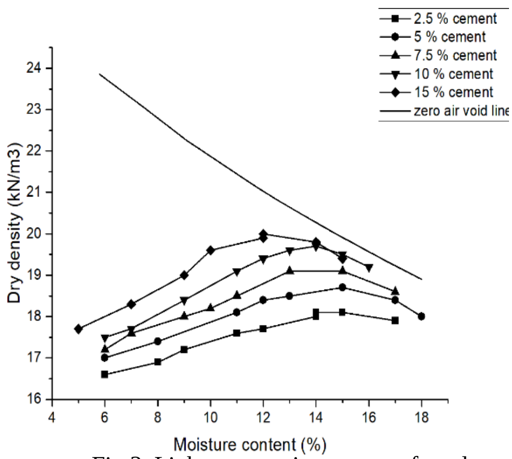


Fig 3. Light compaction curves of sand cement mixes

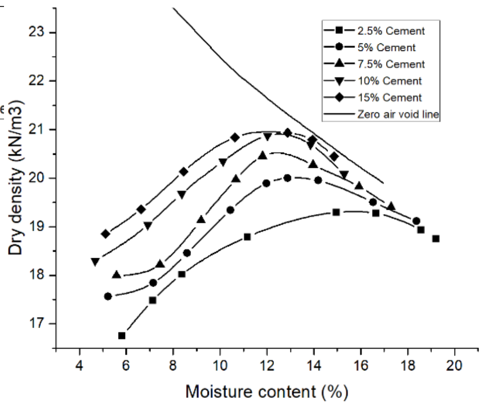
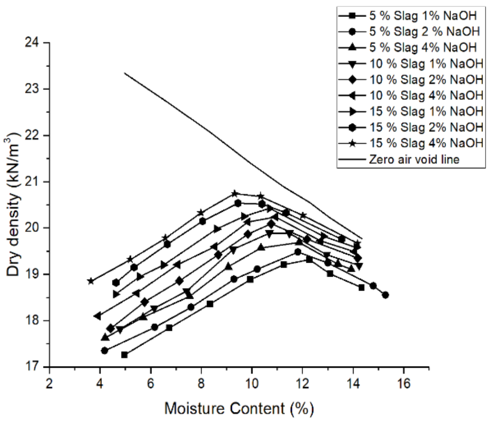
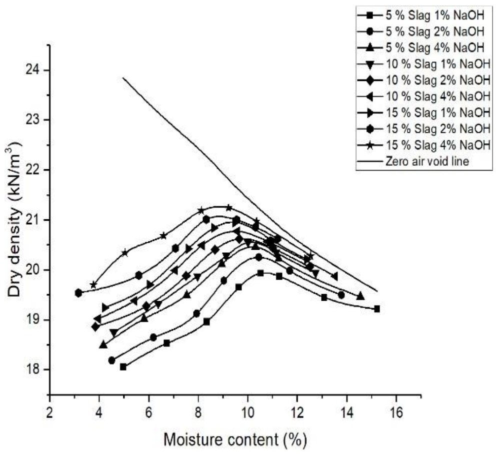


Fig 4. Heavy compaction curves of sand cement mixes mixes





4.2 Delayed compaction

Sand-cement mixture, sand-lime mixture and slag based geopolymer samples are mixed with obtained optimum moisture content (OMC) from the compaction characteristics graphs. The samples are compacted by light compaction and heavy compaction test after a delay period of 0,3,6,12,24,48,72 and 168 hours. For light compaction of sand-lime mix with increasing delay time the dry unit weight is reducing. From Fig 7 it is observed that for 48 hours delay period and 2.5% lime content the MDD is 14.1 kN/m3 and for 48 hours delay period and 15% lime content the same is 17.3 kN/m3 i.e. increase in MDD by 22.69 %. For heavy compaction of sand-lime mix from fig 8 it can be observed that for 168 hours delay period at 5% lime content MDD is 17kN/m3 and 15% lime content has 18.2 kN/m3. It is also observed that for the higher percentage of lime or cement content the decrease in MDD is rapid initially with increasing delay time and then it stabilizes but for the lower percentage of lime or cement content the slope of the curve is lesser from the beginning. Compared to lime for sand-cement mix 2.5% cement content the MDD is 15 kN/m3 and for 48 hours delay period and 15% cement content the same is 18.2 kN/m3 i.e. increase in MDD by 21.33 % it can be seen in Fig 9. For heavy compaction of sand-cement mixes from fig 10 it can be concluded that for 168 hours delay period at 5% cement content MDD is 16.4 kN/m3 and at the same period of time 15% cement has 17.8 kN/m3. In case of slag based geopolymer mixes for 5% slag and 1% NaOH for a delay period of 72hours MDD is 14.5 kN/m3 and for 15% slag 1% NaOH in case of same delay period MDD is 16.4 kN/m3 as shown in fig 11. For heavy compaction as shown in fig 12 slag 1% NaOH for a delay period of 24hours MDD is 17.8kN/m3 and for 15% slag 1% NaOH of the same delay period MDD has the value 19.7kN/m3 i.e. increase in MDD by 10.67%.

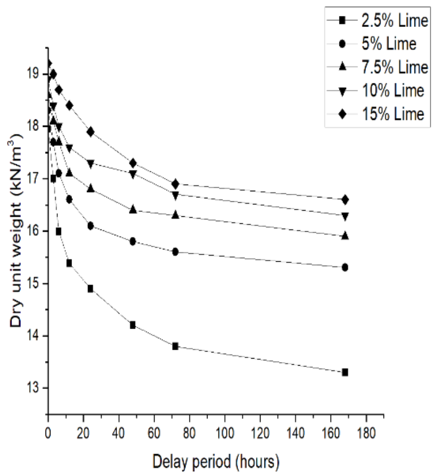


Fig 7. Variation of dry unit weight of sand lime mixes with delay time (light compaction)

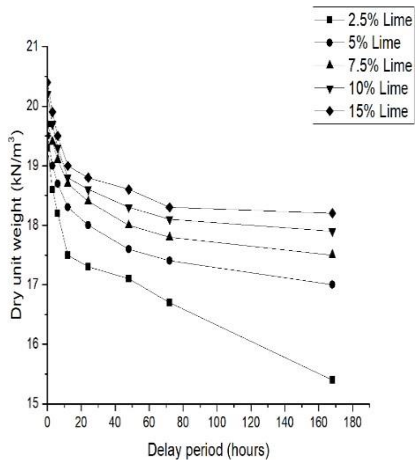


Fig 8. Variation of dry unit weight of sand lime mixes with delay time (heavy compaction)

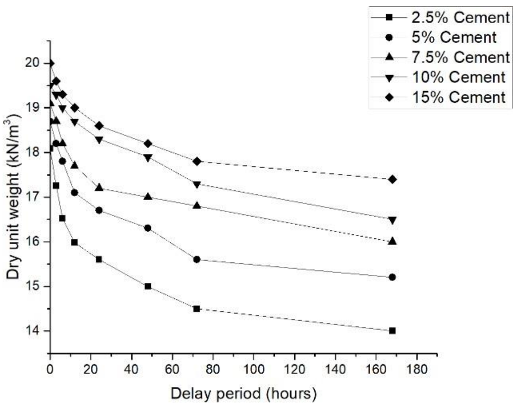


Fig 9. Variation of dry unit weight of sand cement mixes with delay time (light compaction)

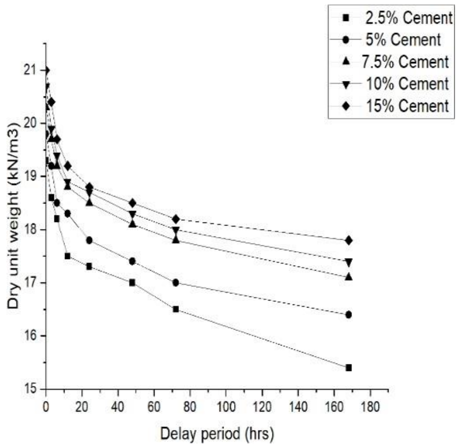


Fig 10. Variation of dry unit weight of sand cement mixes with delay time (heavy compaction)

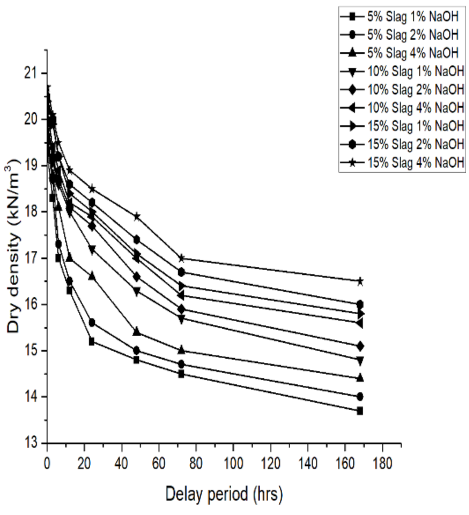


Fig 11. Variation of dry unit weight of slag based geopolymer with delay time (light compaction)

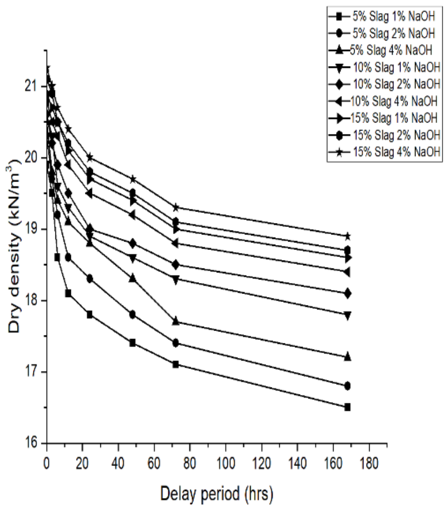


Fig 12. Variation of dry unit weight of slag based geopolymer with delay time (light compaction)

4.3 Unconfined compression strength

The unconfined compressive strength for sand lime mixture is increased with increase in percentage and decrease with the delay period. 10% lime for 7-day curing period 0 hour delay the unconfined compressive strength is 234.5kPa and for 7 days delay period 102.4kPa i.e., the compressive strength is decreased by 56.33 % as shown in fig 13. The unconfined compressive strength for sand cement mixture is increased with increase in percentage and decrease with the delay period same like sand-lime mixture. 10% cement for 7-day curing period 0 hour delay the unconfined compressive strength is 369.6kPa and for 7 days delay period 214.2kPa i.e., the compressive strength is decreased by 42.04 % as shown in fig 14. The unconfined compressive strength for slag based geopolymer mixture is increased with increase in percentage of slag and NaOH activator and decrease with the delay period. 10% Slag 1% NaOH activator 7 day curing period with 0hour delay the unconfined compressive strength value is 261 kPa and 48hour delay period 152 kPa and for 10% slag 4% NaOH solution the 7 day curing period with 3hour delay 336 kPa and 48hour delay 265 kPa as shown in fig 15.

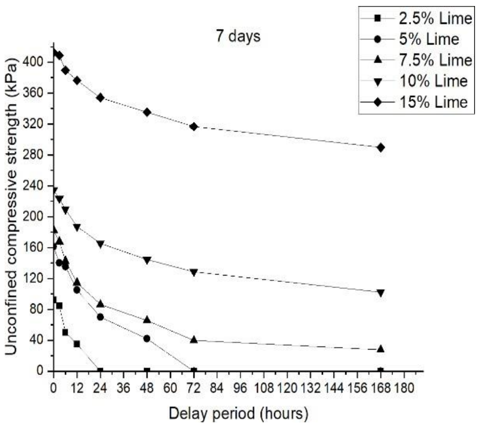


Fig 13. Variation of unconfined compressive strength for different percentages of lime (7 days)

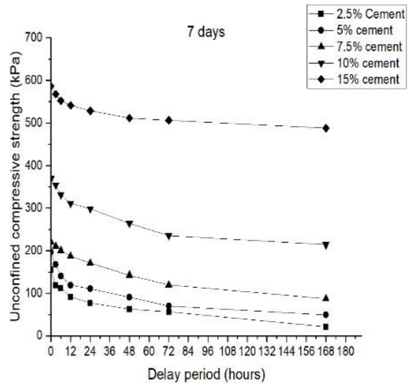


Fig 14. Variation of unconfined compressive strength for different percentages of cement (7 days)

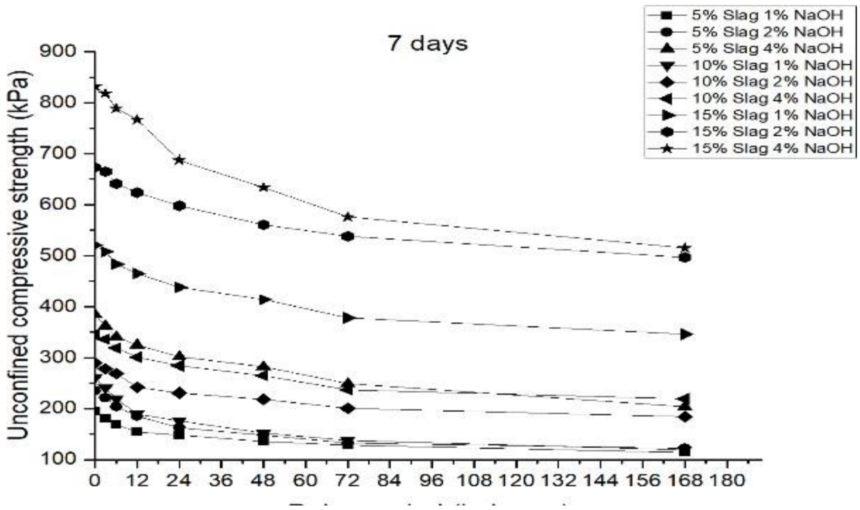


Fig 15. Variation of unconfined compressive strength for different percentages of slag based geopolymer (7days)

5 Conclusion

1. From the above experiments, it is concluded that, in both light and heavy compaction tests the optimum moisture content reduced while maximum dry density increased by increasing of cement, lime contents and slag based geopolymer content.

2. In delayed compaction, dry unit weight reduced with the time. This reduction of dry unit weight is due to hydration.

3. For 7.5% cement, dry density is decreased by 18% for 24 hours when compared to 12 hours and 12% in case of lime. It indicates that reduction in dry unit weight is faster in case of cement.

4. For 15% slag 4% NaOH alkaline activator the dry density is decreased by 16% for 24 hours when compared to 48 hours.

5. It is also observed that, unconfined compression strength decreased with delay time and increased with the increment of cement, lime and slag based geopolymer.

6. It is observed that the unconfined compressive strength value for 15% cement is 29% more when compared to that of 15% lime after 7days curing period.

7. In unconfined compressive strength test when compared to cement and lime, slag based geopolymer specimens has given good results.

6 References

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