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Swell–Shrink Studies on Stabilized Quarry Dust Cushion for Expansive Soil

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Abstract*—Increase in the construction activities has enhanced the demand for aggregates which lead to the liberation of huge amount of quarry dust consequently. Highway construction is one of the prominent fields for the use of quarry dust in abundance. However, presence of expansive soil in the most of integral part of India leads to questioning on the suitability of quarry dust for pavement construction. Hence, an attempt has been made to understand the potential of quarry dust cushion to prevent seasonal swell–shrink in expansive soil. Comprehensive studies of linear swell and cyclic swell–shrink of expansive soil with the use of lime treated quarry dust cushion of different thickness have been carried out. The results revealed that increase in the thickness of lime treated quarry dust cushion significantly reduces the swell strain of the expansive soil. The present study proposed that lime treated quarry dust cushion layer of thickness equivalent to soil layer can be used effectively and economically for the pavement construction in expansive soil.

Keywords: cyclic swell–shrink, cushion, durability, lime, quarry dust

I. Introduction:

The enormous quarry dust with estimated reserves of more than 5,000 million cubic meters produces in several states of India by the aggregate crusher units as a bye product during crushing of rubble [i]. It has been reported that the each crusher unit generates about 20 to 25% of the total production as the waste material–quarry dust [ii]. Stacking and disposal of quarry dust creates a huge threat to the environment and health hazards for plant life and living things due to pollution of water and air. Bulk utilization of quarry dust is required to overcome from the possible problems which is only possible through geotechnical applications. Several studies have been carried out to utilize the quarry dust as a suitable material for highway construction [ii−x]. Tepordei and Valentin [iii] reported that the quarry waste improves the geotechnical properties of soils such as reduction in liquid limit, reduction inplasticity, increase in maximum dry density, decrease in optimumwatercontent (OWC) and increase in unsoaked (immediately after molding) and soaked (immersed in water for 96 hr.) CBR values [iv]. Gupta et al. [ix] investigated by using an optimum quarry dust content of 40% for the stabilization of black cotton soil. Quarry dust samples yielded high CBR values indicating its potential as a good sub–base material [vi]. Studies on the shear strength of soil–quarry dust mixtures revealed the improvement in the engineering properties of soil and proved to be a very promising substitute for sand. It is reported that the strength and stiffness of the subgrade need to be measured for the design of road pavements [xi]. However, use of quarry dust as cushion material for the highway construction has not investigated and is prime motive of the present work.

Further, major portions of India (20% area) and particularly Vijayawada region which is on the coastal plains of Krishna river are covered with expansive soils. It is well known that construction of highway or pavement in the expansive soil creates severe problems due to its undesirable volume change behaviour upon temporal variation [xii]. The damages caused by the expansive soils have received the universal attention in view of the serious economic losses for many countries of worldwide [xii −xiv]. The several remedial techniques that are developed previously to overcome the problem caused by expansive soils which include as replacement of existing soil with suitable one, controlling the moisture, alteration and modification using chemical stabilizers, application of the adequate surcharge pressure, using various geosynthetic materials, provision of suitable cushion materials, construction of suitable substructure (underreamed piles, belled pier foundation, mat foundation, recently piled footings, anchored granular piles) and stiffening superstructure [xiii, xv-xxii].

Previously, sand and cohesive non–swelling soils (CNS) are used widely as cushion materials to prevent the damage to the structure caused by expansive soil. However, sand cushion was found to be inconsistent under varied site conditions in compared to CNS cushion. Cohesive non–swelling soil (CNS) is used as a good cushion material for reducing the swell, but is not observed effective under wetting–drying cycle. It is reported that increase in the number of cycle reduces the effectiveness of CNS cushion with time periods. Also, accessibility of CNS materials at several construction sites is very difficult. However, the thickness of CNS cushion depends on the allowable value of swell and for a given value of swell; an increase in cohesion value of CNS cushion causes a reduction in the thickness of cushion. Efforts are made by several researches to develop the artificially prepared CNS materials to sort out the disadvantage of non availability of natural CNS materials at the required location. Expansive soils are modified artificially for cushion materials by using chemical stabilizers [lime, calcium chloride($CaCl_2$)]alone or, in combination of waste binders [fly ash, rice husk ash (RHA)]. Further, various waste materials such as RHA, GGBS and Fly ash have introduced for the cushion materials alone or, after treating by different calcium based additives. Sivapullaiah et al. [xxii] revealed that RHA treated with lime or cement reduces significantly the heave of expansive soil and withstands the adverse effect of wetting–drying cycle due to seasonal variation. The soil cushion stabilized with lime and cement subjected to all the wetting and drying cycle controls swell–shrink behaviour successfully. Katti and Katti[xxiv] have recommended by preparing an artificial CNS material of mixing lime/gypsum or sand with the native expansive soil. Rao et al. (2011) reported after using the fly ash, granulated blast furnace slag (GBS) and ground granulated blast furnace slag (GGBS) cushions that cement–stabilized GGBS is the most effective of all in reducing heave. However, potential of quarry dust cushion to combat with swell–shrink of expansive soil for highway construction purpose has not been practiced and needs to be investigated.

In the present paper, the works have been carried out to find out the role of quarry dust cushion to control the heave of expansive soil and their potential to counteract the damage caused by wetting–drying cycles. The various swell and cyclic swell–shrink tests have been performed on the expansive soil by using lime treated quarry dust cushion. Tests have been carried out on the specimens prepared at different thickness ratios of cushion (Tc) to soil (Ts) layer. Further, proper thickness of cushion materials has been proposed

II.Materials and Methodology Followed

Materials used

The geotechnical properties of soil are presented in Table 1. The soil was collected from Kanuru Village, Vijayawada, Andhra Pradesh, India and obtained by open excavation from a depth of 2 m from the existing ground level. The soil was oven dried at a constant temperature and pulverized. The soil passed through 425 micron Indian Standard (IS) sieve was used for experimental purpose. Based on IS classification, the soil is classified as highly expansive soil and highly plastic clayey soil.

The physical properties of non–plastic (NP) quarry dust obtained from Kethanakonda village crusher near Vijayawada, India is presented in Table 2. The quarry stone was whitish hard granite metal with predominate quartz mineral and small percentage of biotite and olivine. The physical properties showed the presence of sand sized particles predominantly in the quarry dust. The specific gravity of quarry dust is found to be 2.72 which are greater than soil (i.e. 2.65). The quarry dust was found to be non plastic.

Methodologies followed

Sample preparations

The schematic representation of experimental setup is illustrated in Fig. 1. Mild steel cylindrical mould of size (20 cm × 20 cm) internal diameter was used for the preparation of specimens containing both soil and quarry dust cushion layer. Maximum dry density (MDD) and Optimum Water Content (OWC) are used to prepare specimen of expansive soil in the mould. Also, quarry dust cushion treated with 3% lime is compacted at their respective at MDD and OWC at different thickness ratios (Tc/Ts) of 0.25, 0.50, 0.75 and 1.0. The compacted soil sample was transferred to another mould of size 25 cm diameter and 40 cm height which is represented as a test mould. Then coarse sand was used to fill the remaining gap between test mould and sample mould. Thereafter, the compacted soil layer overlaid with the compacted cushion layer of lime treated quarry dust of varying thickness ratios. The cover plate placed on the top of entire sample having soil and quarry dust cushion layer. The measurement of the vertical deformation was captured by placing dial gauge on the cover plate. The entire setup was submerged in a water tank and started to take the dial gauge reading. The reading was taken continuously till no further movement in dial gauge reading.

Cyclic swell–shrink test

The entire setup was removed from the water tank after reaching the constant dial gauge reading, and kept outside for a day to drain out the excess water. The same was dried in the oven for four days in the oven maintaining a constant temperature of 50º C. The readings are taken after removing from the oven to know the amount of shrink in the samples. The setup of soil and cushion materials are again kept in to the tank and submerged with water and dial gauge reading was taken. The similar procedure was repeated for a minimum of five cycles.

Table 1 Geotechnical properties of expansive soil

Description	Value
Soil classification	CH
Specific gravity	2.65
Clay content, %	100
Liquid limit, %	72
Plastic limit, %	32
Plasticity index, %	40
Shrinkage limit, %	18
Optimum water content, %	24
Maximum dry density, gm/cm^3	1.48
Unconfined compressive strength, Kg/cm^2	1.92
Differential free swell, %	125
Swell pressure, Kg/cm^2	0.75

Table 2 Physical properties of quarry dust

Description	Quarry Dust
Gravel, %	13.50
Sand, %	72.50
Silt, %	14.00
Clay, %	–
Specific gravity	2.72
Liquid limit, %	–
Plastic limit, %	Non Plastic
Plasticity index, %	Non Plastic
Optimum water content, %	9.50

Maximum dry density, Kg/cm^3	1.96

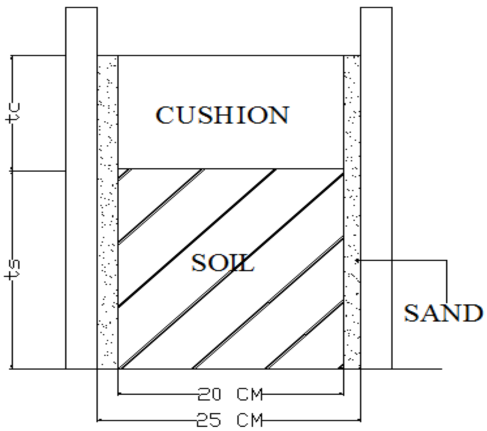

Fig. 1 Schematic representation of sample preparation of soil-cushion layers for test

III. Results and Discussion

Swell behavior

The swell behaviour of expansive soil with lime treated quarry dust cushion of varying thickness ratios of cushion (Tc) and soil (Ts) layer (0.25, 0.5, 0.75 and 1.0) is shown in Fig. 2. It is observed that swell strain increased continuously with an increase in time periods and attained its maximum after 12 days. However, it is interesting to observe that increase in the thickness of cushion (Tc) drastically reduces the swell strain of expansive soil.

The swelling of expansive soil eliminates almost with the use of cushion layer equivalent to the thickness of soil layer (Tc/Ts = 1). The swell strain of expansive soil reduces to 5.82, 2.83, 1.14 and 0.025 % with increase in the thickness of lime treated quarry dust cushion layer by 0.25, 0.5, 0.75 and 1.0, respectively. Hence, it is observed that ratio of Tc/Ts for one showed beneficial to control the swell of expansive soil by using lime treated quarry dust cushion. The drastic reduction in the swell strain of expansive soil with increase in the thickness of cushion layer of lime treated quarry dust is due to the increase in the surcharge pressure to the expansive soil as the specific gravity of quarry dust is higher than soil, and thereby, consequent increase in the density. Further, addition of 3% lime to quarry dust forms the cementitious gels such as Calcium Silicate Hydrate (CSH), Calcium Aluminate Hydrate (CAH) and Calcium Aluminate Silicate Hydrate (CASH). These cementitious compounds form the compacted and stronger cushion layer which is adequate enough to withstand the vertical pressure exerted by the expansion soil. Hence, increase in the surcharge pressure and formation of stronger cushion layer attribute to the reduction in swell strain of expansive soil.Cyclic swell–shrink behaviour of soil–lime treated quarry dust cushion of varying thickness is shown in Fig. 3.It is observed that percentage of swell in each cycle is higher than that of shrinkage of expansive soil. Further, percentage of swell and shrink for any cycle of wetting and drying at any Tc/Ts ratios are almost sameIt is revealed that the number of wetting–drying cycle does not influence the swell–shrinkage of expansive soil. However,it is interesting to observe that increase in the thickness of cushion layer reduces drastically the percentage of swell–shrinkage and eliminatescompletely after using the thickness of cushion layer equivalent to that of the soil layer (i.e. Tc/Ts = 1). This shows an increase in the durability of lime treated quarry dust cushion. The increase in durability is due to the formation of stronger cushion layer by binding and filling of quarry dust particles with cementitious compounds.

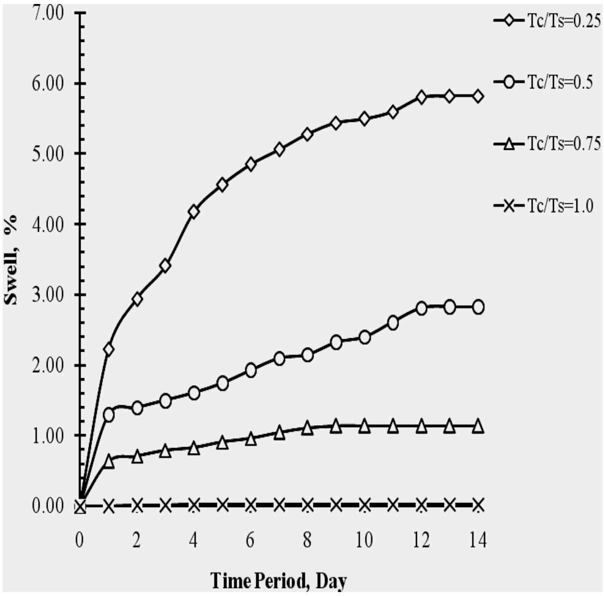

Fig. 2 Swell behaviour of expansive soil with different thickness of lime treated quarry dust cushion

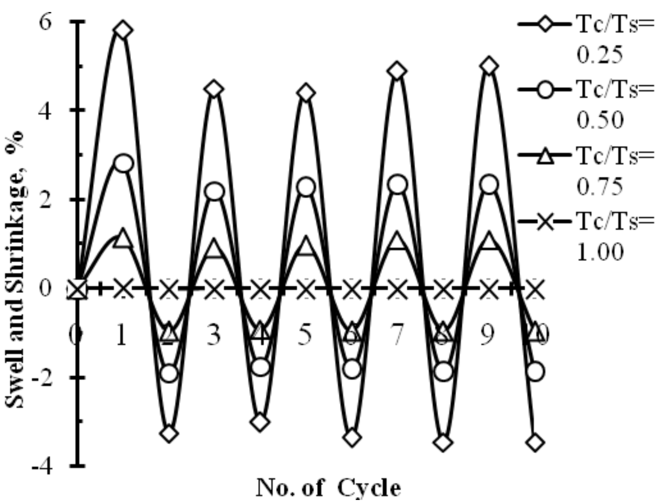

Fig. 3 Cyclic swell–shrinkage behaviour of expansive soil with different thickness of lime treated quarry dust cushion

IX. Conclusion

The present study clearly brought out the role of lime treated quarry dust cushion to control the heave of expansive soil. Also, effect of wetting–drying upon the durability of quarry dust cushion is also investigated. The following important conclusions are drawn from the present work:

- The heave of expansive soil reduces drastically with increase in the thickness of lime treated quarry dust cushion. This is due to the increase in the surcharge pressure with increase in thickness of cushion and formation of stronger and compacted cushion matrix with cementitious compounds. Further, the lime treated quarry dust withstands an adverse impact of wetting–drying cycles due to seasonal moisture variation.
- Thickness of lime treated quarry dust cushion layer equivalent to expansive soil layer is proposed for the effective utilization of quarry dust to combat with heave induced by expansive soil.
- Formation of cementitious compounds and thereby binding and filling of quarry dust matrix with lime leads to form the stronger and compacted matrix which is the key factor to improve the volume change behaviour and durability of expansive soil overlaying by the cushion materials of lime treated quarry dust

References

i. *Madhavan P., and Raj S., Budhpura 'ground zero' sandstone quarrying in India, India Committee of the Netherlands, Mariaplaats, LH Utrecht, Netherlands, 2005.*

ii. *Sridharan A., Soosan T. G., Jose B. T., and Abraham B. M., "Shear strength studies on soil–quarry dust mixtures," Geotechnical & Geological Engineering, 24(5), 1163–1179, 2006.*

iii. *Tepordei and Valentin V., Crushed stone, Bureau of Mines Annual Report, Washington D.C., 1992.*

iv. *Soosan T. G., Jose B. T., and Abraham B. M., "Utilization of quarry dust to improve the geotechnical properties of soils in highway construction," Geotech. Test. J., 28(4), 1–9, 2005.*

v. *Soosan T.G., Jose B.T. and Abraham B.M., "Improvement of ground and highway sub–bases using quarry waste," Proceedings of International seminar on civil engineering, ICCE, 2001, IISc. Bangalore, pp.730–737, 2000.*

vi. *Soosan T.G., Jose B.T. and Abraham B.M., "Use of quarry dust in embankment and highway construction," Proceedings of Indian Geo–Technical Conference, December, Indore, pp. 274–277, 2001.*

vii. *Kandolkar S. S., and Mandal J. N., "Effect of reinforcement on stress–strain behavior of stone dust," International Journal of Geotechnical Engineering, 8(4), 383–395, 2014.*

viii. *Kandolkar S. and Mandal J., "Behavior of Reinforced–Stone Dust Walls with Backfill at Varying Relative Densities," J. Hazard. Toxic Radioact. Waste, 10.1061/(ASCE)HZ.2153–5515.0000287, 04015010, 2015.*

ix. *Gupta A.K., Sachan A.K., Sahu A.K. and Kumar S., "Stabilization of black cotton soil using crusher dust –A waste product of Bundelkhand region," Proceedings of Indian Geotechnical Conference, Allahabad, pp. 308–311, 2002.*

x. Sabat A.K. and Das S.K., "Design of low volume rural roads using lime stabilized expansive soil– quarry dust mixes subgrade," Indian Highways,Vol .37(9) pp. 21–27, 2009.

xi. Powell W. D., Potter J. F., Mayhew H. C. and Nunn M. E., The structural design of bituminous roads (No. LR 1132 Monograph), 1984.

xii. Mitchell J. K. and Soga, K., Fundamentals of soil behavior (Vol. 422). New York: Wiley, 1976.

xiii. Chen F. H., Foundations on expansive soils Elsevier Scientific Publishing Co., Amsterdam, 1975.

xiv. Petry T. M. and Little D. N., "Review of stabilization of clays and expansive soils in pavements and lightly loaded structures—History, practice, and future," J. Mater. Civ. Eng., 146, 447–460, 2002.

xv. Al–Rawas A. A. and Goosen M. F., Expansive soils: recent advances in characterization and treatment, Taylor & Francis, 2006.

xvi. Kota P. B., Hazlett D. and Perrin L., "Sulfate–bearing soils: problems with calcium–based stabilizers," Transportation Research Record: Journal of the Transportation Research Board, 1546(1), 62–69, 1996.

xvii. Mohan D., Jain G. S. and Sharma D., "Foundation practice in expansive soils of India," Proc., 3rd Int. Conf. on Expansive Soils, Haifa, Israel, 319–324, 1973.

xviii. Mohan D. and Rao B. G., "Moisture variation and performance of foundations in black cotton soils in India," Proc., Symp. on Moisture Equilibria and Moisture Changes in Soils Beneath Covered Areas, Butterworths, Australia, 143–155, 1965.

xix. Puppala A. J., Wattanasanticharoen E. and Hoyos L. R., "Ranking of four chemical and mechanical stabilization methods to treat low volume road subgrades in Texas," Transportation Research Record. 1819, Transportation Research Board, Washington, D.C., 63–71, 2003.

xx. Murty V. R., "Influence of some treatment alternatives on heave of model walls in expansive soil," Proc., Int. Conf. on Civil Engineering, IISc, Bangalore, India, 917–926, 2001.

xxi. Phanikumar B. R., Sharma R. S., Rao A. S. and Madhav M. R., "Granular pile anchor foundation system for improving the engineering behaviour of expansive clay beds," Geotech. Test. J., 27(3), 279–287, 2004.

xxii. Jha A. K. and Sivapullaiah P. V., "Mechanism of improvement in the strength and volume change behavior of lime stabilized soil," Engineering Geology, 198, 53–64, 2015.

xxiii. Sivapullaiah P. V., SubbaRao K. S. and Gurumurthy J. V., "Stabilization of rice husk ash for use as cushion below foundations on expansive soil," Ground Improv 8(4):137–149, 2004.

xxiv. Katti R. K. and Katti A. R., Behaviour of saturated expansive soil and control methods, Oxford & IBH Pub. Co. Pvt. Ltd., New Delhi, India, 1994.