International Journal of
Advanced Structures and Geotechnical Engineering
ISSN 2319-5347, Vol. 03, No. 01, January 2014

Studies on the utilization of quarry dust to improve the geotechnical properties of lithomargic clay

PURUSHOTHAM G SARVADE[1] and **SITARAM NAYAK**[2]
[1]*Department of Civil Engineering, MIT, Manipal University, Manipal, Karnataka, India*
[2]*Department of Civil Engineering, NITK, Surathkal, Karnataka, India*
Email: pg.sarvade@manipal.edu

Abstract: Environmental pollution is one of the major problems associated with the infrastructural developmental activities due to rapid urbanization and fast growing industries in Dakshina Kannada, Udupi and adjacent districts of Karnataka State. Hence efforts are to be made for controlling pollution due to disposal of wastes generated from these industries and conversion of these unwanted wastes into utilizable material for various applications. The quarry dust, a by-product from the crushing process during quarrying activities, is one of the waste materials which constitute approximately 25% of the output of each crusher unit. This byproduct is left in the neighborhood of the quarry causing environmental pollution and serious health hazards. Hence an experimental study was undertaken to check the suitability of using quarry dust as a stabilizer to improve the geotechnical properties of lithomargic clay. Lithomargic clay is a dispersive type of soil which is highly susceptible to erosion abundantly available in the western coastal belt of Southern India. The results showed that the geotechnical parameters of the lithomargic clay are improved substantially by the addition of quarry dust. There was a good improvement in the consolidation values of the lithomargic clay blended with the quarry dust because of its good permeability and also the variation in water content does not seriously affect its desirable properties. The settlement analysis of the lithomargic clay and the lithomargic clay blended with 10%, 20%, 30%, 40% and 50% quarry dust for a square footing is also carried out using Plaxis 3D. And it was found that there is a decrease in the settlement and increase in the load carrying capacity when blended with quarry dust. The results obtained in the present study will help to solve the problems associated with the lithomargic clay to a considerable extent and also utilization of the waste contributing towards economy in construction.

Key words: *Environmental pollution, Lithomargic clay, Quarry dust, Plaxis 3D*

Introduction

Air pollution is a major environmental problem in the developing and developed countries of the world. Quarry dust is one of the frequently criticized nuisances due to its health and environmental implications on surrounding community. Due to the high demand for rubble and aggregates for construction purposes, rubble quarries and aggregate crushers are very common. Out of the different quarry wastes, quarry dust is one, which is produced in abundance. It constitutes about 25% of the output of each crusher unit. Quarry dust consists mainly of excess fines generated from crushing, washing and screening operations at quarries. The material properties of this waste vary with the source, but are relatively constant at a particular site. Gradation of this material does not satisfy the specification requirements for concrete works. This is mainly due to fine state of quarry dust resulting in large specific surface. Normally this waste product is left in huge heaps in the neighborhood of the quarry causing serious health hazards. Further, the space required for waste disposal is another problem faced by the industry. Quarry dust exhibits high shear strength, which is highly beneficial for its use as a geotechnical material. It has good permeability and variation in water content does not seriously affect its desirable properties. In this background, any attempt to utilize this waste in developmental activities is relevant. There are a number of geotechnical applications for quarry dust (in embankments, backfills and as sub-base). Problems associated with the construction of highways over clayey subgrade can be reduced significantly by mixing with quarry dust (Soosan et al., 2005).

Lithomargic clay is locally available whitish, pinkish or yellowish silty sand. It is mainly composed of hydrated alumina and kaolinite powder This soil is present in between weathered laterite and hard granite gneiss and is present at a depth of 1-3 meters below the top lateritic outcrop. This type of soil is abundantly available in the western coastal belt of Southern India, starting from Cochin to Goa. These soils are the product of tropical or subtropical weathering. Their strength is high in dry conditions, whereas significant reduction of strength takes place when there is an increase in moisture content. These types of dispersive soils are highly susceptible to erosion (Ramesh et al., 2007). As long as this soil is confined and dry, there is a very little or no problem, but on the exposure in a cutting or when it comes in contact with water, it loses its strength drastically. Slope failures, landslides etc., are quite common in this type of soils (Ravishankar et al., 2006). The infrastructural developmental activities due to rapid urbanization and fast growing industries in coastal Karnataka are forcing the civil engineers to put to the best use of even the poorest sites available and

discarded by our ancestors. These poor sites are characterized by low bearing capacities and large settlements. Low lying agricultural and marshy lands in and around is being converted into estates with locally available soils mentioned above as lithomargic clay. Large hills are cut for these purposes. These filled up areas pose problems of low bearing capacity as well as excessive settlements because of improper compaction and poor drainage. (Achari, R. 2005).
Modification by admixtures is a method of modifying the soils by the mechanical addition of granular materials or chemical compounds. The soil stabilization is the collective term used to denote any physical, chemical or biological method or any combination of such methods employed to improve certain properties of natural soil to make it serve adequately for an intended engineering purpose. The different uses of soil pose different requirements of mechanical strength and a resistance to environmental forces, controlling method to be used for the stabilization (Krishnamurthy, 1999).

PLAXIS is a software based on the finite element method and intended for 2-Dimensional and 3-Dimensional analysis of deformation and stability of soil structures. Settlements depend on local soil conditions and on the construction method. Especially for pile-raft foundations there is an important interplay between the pile, the raft and the soil to support the forces from the upper structure. In this interplay deformations are a key factor. Such a situation can only be analysed effectively by means of three-dimensional finite element calculations in which proper models are incorporated to simulate soil behaviour and soil-structure interaction. PLAXIS 3D Foundation offers these facilities. To understand the deformation trends within the soil mass a series of three dimensional finite element analyses on a prototype square footing was carried out.

The results obtained in the present study will help to solve the problems associated with the lithomargic clay to a considerable extent and also utilization of the waste contributing towards economy in construction.

Material and methods

Soil: Lithomargic clay was collected from Kavoor of Dakshina Kannada District, Karnataka (India). A series of tests were conducted in the laboratory as per IS specifications to get the geotechnical properties (Fig.1).

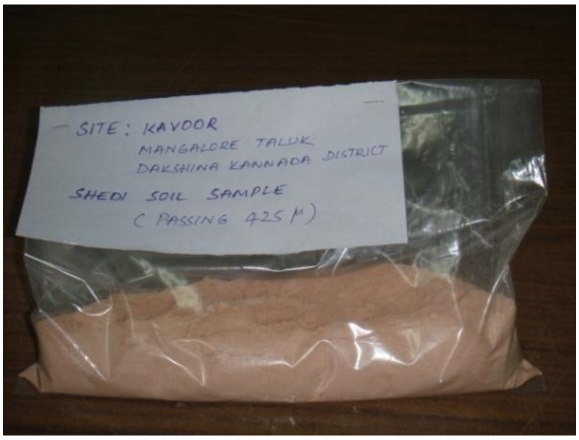

Fig. 1 Lithomargic clay

Quarry dust: The quarry dust used for stabilization was obtained from a crusher unit near Athrady village of Udupi taluk (India)(Fig.2). The particle size distribution of quarry dust is shown in Fig. 3. The major constituents of quarry dust was obtained by conducting XRay Diffraction test (Fig. 4).

Fig. 2 Quarry dust

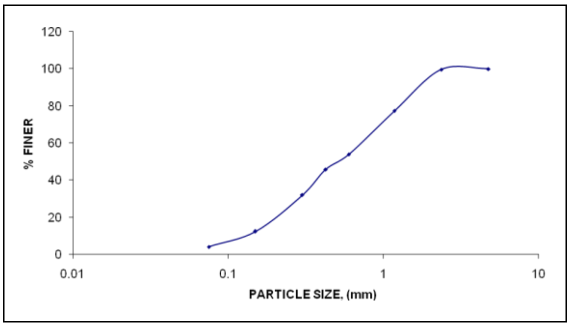

Fig. 3 Grain size distribution of Quarry dust

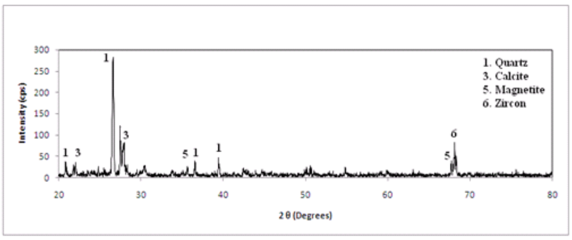

Fig. 4 XRD pattern of Quarry dust

Sample preparation and testing:
For each trial, uniform mixing was maintained. A detailed laboratory investigation was carried out to study the effect of quarry dust on lithomargic clay and the behaviour of stabilized soil. The soil for stabilization was mixed with different percentages of quarry dust (10%, 20%, 30%, 40% and 50%). These soils mixed with quarry dust were tested to get various geotechnical properties. The samples for strength properties were prepared at maximum dry density and optimum moisture content with the curing period of seven days.

Results and discussion
Geotechnical properties of lithomargic clay stabilized with quarry dust:
The summary of results obtained by stabilizing lithomargic clay with quarry dust (0%, 10%, 20%, 30%, 40% & 50%) is shown in Table 1.

Table 1: Geotechnical properties of lithomargic clay stabilized with quarry dust

Parameter	**Percentage of quarry dust added**					
	0%	**10%**	**20%**	**30%**	**40%**	**50%**
Specific Gravity	2.58	2.58	2.60	2.60	2.61	2.62
Liquid limit (%)	62	54.3	45.5	42.3	40.3	30.7
Plastic limit (%)	38.8	36.5	30	29.1	31.1	25.0
Shrinkage limit (%)	31.8	30.4	28.5	27.3	26.1	23.6
Plasticity Index (%)	23.2	17.8	15.5	13.2	9.2	5.7
Maximum dry density $(\gamma_d)_{max}$ (kN/m^3)	15.7	16.0	16.5	17.0	17.4	18.4
Optimum moisture content (%)	22.5	22.0	20.0	17.6	16.6	15.4
UCC Strength, kPa	304	354	598	353	141	103
UU: Angle of Internal friction, φ	21°	25°	26°	28°	29°	30°
UU: cohesion value, c (kPa)	33.34	32.36	29.42	22.56	20.59	19.61
Coefficient of permeability, k (m/day)	0.00321	0.01313	0.02432	0.0355	0.0467	0.05789

Table 2: Input parameters of Lithomargic clay, quarry dust stabilized Lithomargic clay

	Max. dry density (kN/m^3)	**OMC %**	**Modulus of elasticity E (MPa)**			**Cohesion c (kN/m^2)**	**Angle of internal friction Φ°**	**Coefficient of Permeability k (m/day)**	**Poisson's ratio μ**
			0.5	**1.0**	**1.5**				
Lithomargic clay	15.7	22.5	2.66	3.54	4.25	33.34	21	0.00321	0.33
+10% QD	16	22	3.19	3.71	4.6	32.36	25	0.01313	0.35
+20% QD	16.5	20	3.89	4.78	5.66	29.42	26	0.02432	0.365
+30% QD	17	17.6	4.6	5.3	6.37	22.56	28	0.03551	0.38
+40% QD	17.4	16.6	5.31	6.54	7.79	20.59	29	0.04671	0.39
+50% QD	18.4	15.4	5.84	6.9	8.32	19.61	30	0.05789	0.40

The results showed that the geotechnical parameters of the lithomargic clay are improved substantially by the addition of quarry dust (Nayak et al., 2010). This is mainly because of the high shear strength of the quarry dust. There is a good improvement in the consolidation values of the lithomargic clay blended with the quarry dust because of its good permeability and also the variation in water content does not seriously affect its desirable properties.

Settlement analysis of lithomargic clay stabilized with quarry dust:

A series of three dimensional finite element analyses on square footing was performed to understand the deformation trends within the soil mass. The analysis is performed using the finite element program PLAXIS software package (Fig.5).

Behavior of square footing on lithomargic clay stabilised with quarry dust:

The settlement analysis of the lithomargic clay and the lithomargic clay stabilized with 10%, 20%, 30%, 40% and 50% quarry dust for 1.5m x 1.5m footing is carried out using the Plaxis 3D and the results are presented in Table 3 and Fig. 6. From Table 3 and Fig. 6, it is clear that as the percentage of quarry dust increases the settlement decreases.

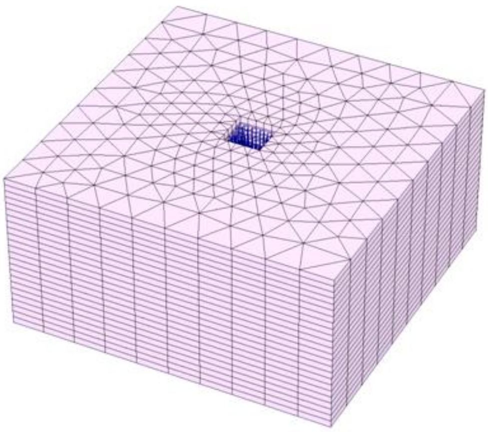

Fig. 5 Finite element model (3D) for 1.5m x 1.5m footing on Lithomargic clay

Table 3 - Settlement of 1.5m x 1.5m footing on quarry dust stabilized lithomargic clay

Load intensity in (kPa)	Settlement (mm)					
	Lithomargic clay	10% Quarry dust	20% Quarry dust	30% Quarry dust	40% Quarry dust	50% Quarry dust
10	2.52	2.41	1.87	1.74	1.46	1.44
50	11.2	10.59	8.18	7.31	5.9	5.55
100	23.05	21.7	16.71	16.1	13.74	13.13
150	36.56	33.53	26.16	25.18	22.31	21.01
200	51.95	46.69	35.9	35.01	30.88	29.19
250	70.51	60.85	46.7	45.27	39.85	37.52
300	94.29	76.8	59.01	58.56	49.66	46.74
350	123.09	95.08	72.55	70.82	60.82	56.3
400	157.79	116.34	88.23	86.22	71.76	67.45

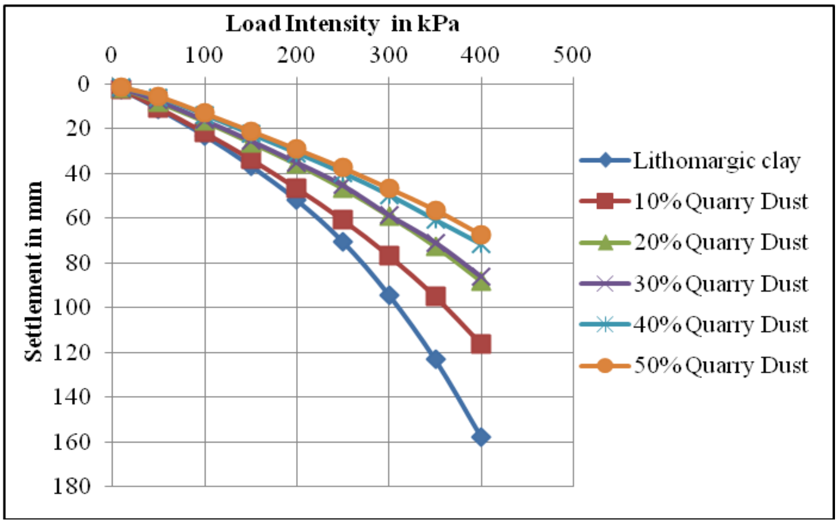

Fig. 6 Settlement vs load intensity for 0% to 50% quarry dust stabilized lithomargic clay

The percentage decrease in the values of the settlement of 1.5m x 1.5m footing on the lithomargic clay stabilized with 10%, 20%, 30%, 40% and 50% quarry dust for 150 kPa load intensity is presented in Table 4.

Table 4 Percentage decrease in the settlement of Lithomargic clay and quarry dust stabilized lithomargic clay

	Settlement in mm at 150 kPa	% Decrease in settlement
Lithomargic clay	36.56	-
Lithomargic clay + 10% Quarry Dust	33.53	8.3
Lithomargic clay + 20% Quarry Dust	26.16	28.5
Lithomargic clay + 30% Quarry Dust	25.18	31.1
Lithomargic clay + 40% Quarry Dust	22.31	39.0
Lithomargic clay + 50% Quarry Dust	21.01	42.5

The percentage increase in the values of load carrying capacity of 1.5m x 1.5m footing on the lithomargic clay stabilized with at 10%, 20%, 30%, 40% and 50% quarry dust for 25 mm permissible settlement is calculated and shown in Table 5.

Table 5 Percentage increase in the load carrying capacity of quarry dust stabilized lithomargic clay

	Load carrying capacity for permissible settlement of 25 mm	% Increase in load carrying capacity
Lithomargic clay	105	-
Lithomargic clay + 10% Quarry Dust	112	6.67
Lithomargic clay + 20% Quarry Dust	141	34.28
Lithomargic clay + 30% Quarry Dust	149	41.90
Lithomargic clay + 40% Quarry Dust	168	60.00
Lithomargic clay + 50% Quarry Dust	178	69.52

Settlement contours for lithomargic clay and lithomargic clay stabilized with quarry dust when foundation is subjected to a load intensity of 150 kpa (typical cases): The settlement contours for 1.5m x 1.5m footing size at 150 kPa load intensity for the lithomargic clay, the lithomargic clay stabilized with 10% quarry dust, the lithomargic clay stabilized with 20% quarry dust, the lithomargic clay stabilized with 30% quarry dust, the lithomargic clay stabilized with 40% quarry dust, the lithomargic clay stabilized with 50 % quarry dust, are presented in Figs. 7, 8, 9, 10, 11 and 12 respectively.

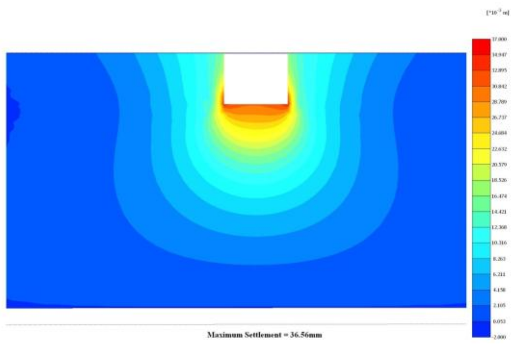

Fig. 7 Settlement contours for lithomargic clay, when 1.5m x 1.5m footing is subjected to a load intensity of 150 kPa

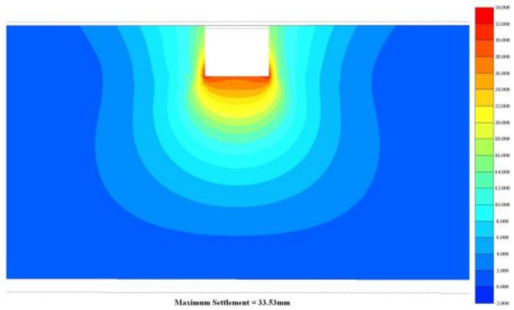

Fig. 8 Settlement contours for lithomargic clay+10% quarry dust, when 1.5m x 1.5m footing is subjected to a load intensity of 150 kPa

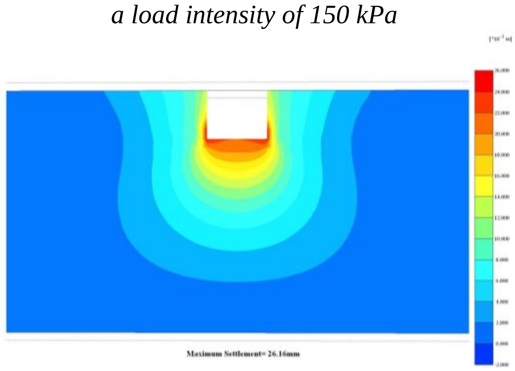

Fig. 9 Settlement contours for lithomargic clay+20% quarry dust, when 1.5m x 1.5m footing is subjected to a load intensity of 150 kPa

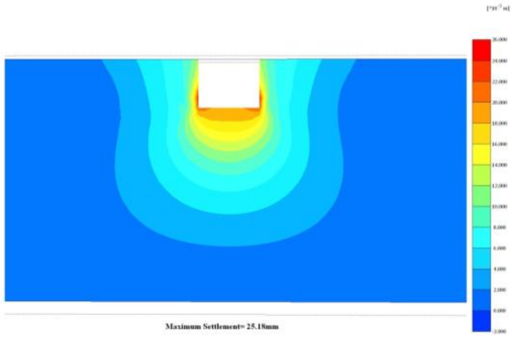

Fig. 10 Settlement contours for lithomargic clay+30% quarry dust, when 1.5m x 1.5m footing is subjected to a load intensity of 150 kPa

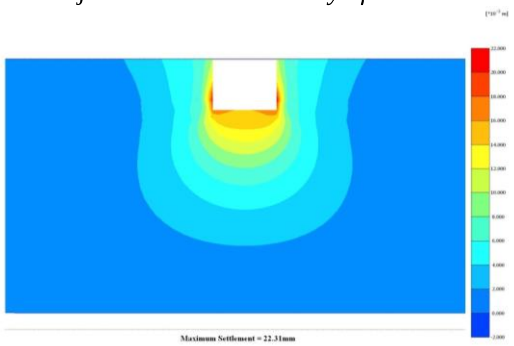

Fig. 11 Settlement contours for lithomargic clay+40% quarry dust, when 1.5m x 1.5m footing is subjected to a load intensity of 150 kPa

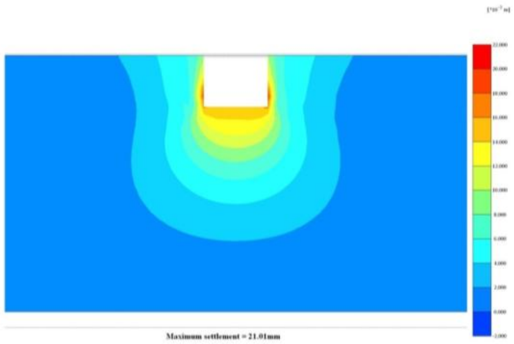

Fig. 12 Settlement contours for lithomargic clay+50% quarry dust, when 1.5m x 1.5m footing is subjected to a load intensity of 150 kPa

Conclusion:

By its nature quarrying has the potential to create dust. The geotechnical characterization of quarry dust and its interaction behavior with soils can lead to viable solutions for its large-scale utilization and disposal. The utilization of the quarry dust as a stabilizing additive to the lithomargic clay is evaluated. A study was undertaken to see the effect of quarry dust on the strength of the lithomargic clay during stabilization. The square footings and the soils are modeled and analyzed using the commercial finite element software PLAXIS 3D, developed by PLAXIS BV, Netherlands, to understand the deformation trends within the stabilized soil mass.

The following conclusions are drawn from the above investigations:

- After the stabilization of the lithomargic clay using the quarry dust, the percentage reduction in liquid limit was about 50.5% when 50 percentage of quarry dust was added. The plasticity index reduced by about 75.4% for 50 percentage quarry dust addition.
- There is an increase of 18% in maximum dry density (MDD) values for the addition of 50% quarry dust. This increase in MDD value is because of the increase in percentage of sand. There is decrease in optimum moisture content from 22.5% to 15.4% (32%).
- For 50% quarry dust addition, angle of internal friction has witnessed an improvement of 43%. The cohesion value has decreased by 41%.
- The finite element analysis with 10%, 20%, 30%, 40% and 50% quarry dust addition with lithomargic clay showed decrease in the settlement and increase in the load carrying capacity.

References:

[1] Achari, R. (2005). “Studies on Anisotropy and Behaviour of Blended Shedi Soil.” M Tech Thesis, Department of Civil Engineering, NITK Surathkal.

[2] Krishnamurthy, (1999). “Ground Improvement Techniques for Soft Shedi Ground.” M. Tech Thesis, Department of Civil Engineering, NITK Surathkal.

[3] Nayak, S., Sarvade, P.G., & Gowda, D.(2010). “Engineering properties of shedi soil before and after quarry dust stabilization”, Indian Highways, Indian Roads Congress, 39-46.

[4] Plaxis 8-3D Foundation software version-2, Manual, PLAXIS bv, DELFT, Netherlands.

[5] Ramesh, H.N. and Nanda, H.S. (2007). “Strength behavior of shedi soil treated with fly ash.”13th ARC, Kolkata , 893-896.

[6] Ravishankar, A.U., Suresh, S.N. and Phanikumar, M.V.S.(2006). “Strength behavior of shedi soil-lime-pondash mixes-an experimental study.” *Highway Research Bulletin*, Indian Roads Congress, 1-7.

[7] Soosan,T.G., Sridharan, A., Jose, B.T. and Abraham, B.M. (2005). “Utilization of Quarry Dust to Improve the Geotechnical Properties of Soils in Highway Construction.” *Geotechnical Testing Journal*, 28(4), 1-10.