Stabilization of Korattur Clay with Quarry Dust for Effective Utilization in Flexible Pavement

J. Jayapal
Assistant Professor, Department of Civil Engineering,
TJS Engineering College,
Chennai-600205 India,

***Abstract*: For nation building, infrastructure development play a key role especially in the case of road sectors. Flexible pavements are comparatively easy and cheap to construct when compared to concrete pavements which show a rigid nature in their behaviour. Flexible pavements are often laid on clay soils (subgrades) as hardly we come across homogeneous sandy soils. Majority of the Clayey soils in the world often pose a problem of swelling and shrinkage to a geotechnical engineer while admitting and loosing water. The main reason behind this quality of clayey soils is because of the chief clay mineral namely montmorillionite. Further the swelling and shrinkage problems in clay subgrades are the prime reason behind potholes, cracking and undulations in the pavement leading to discomfort and lessening the life of vehicle. The quality of clayey soils has be improved substantially with quite a lot of admixtures available either natural or artificial by lot of researchers. This paper discusses the results of the laboratory study conducted on local clayey soil in chennai and its improvement by stabilizing it with admixture say quarry dust. The improvement of clayey soils at last indicate the increment of load resisting capacity which is substantiated with results brought out by various laboratory tests as discussed below. The final conclusion drawn from this investigation is such that quarry dust can be used as a effective stabilizing agent in stabilizing clayey soils for utilizing it in pavements.**

KEY WORDS: Montmorillionite, California Bearing Ratio, Quarry Dust, Compaction, Natural Soil

1. INTRODUCTION

The classification of entire soils of the world splits into clay or sandy type of soils. The latter hardly pose any problem due to seepage of water into it, which is mainly because of its formation from the parent material namely rock. Rather the clayey type of soils are formed by chemical weathering which involves chemical reactions constituting hydration, carbonation and leaching. Due to these aspects the clayey soils swell when it comes in contact with water during winter season and shrink when water is lost due to evaporation during summer. A lot of investigation has been carried out by researchers in modifying the swelling and shrinkage properties of clayey soils. The modification can be brought about by variety of options say by either removing water from those soils, by compacting them, by introducing reinforcements and by additives. The last option is sorted in this study which is found to be economical in certain aspects when the quantum of soil to be stabilized is larger, especially in the case of laying flexible pavements. Early studies have carried out in stabilizing the clayey soil with a lot of additives say flyash [sridharan et al.,], palm oil ash, marble dust, brick kiln dust [Deepa], Cement [Christensen], Bitumen, Egg shell [olarewaju et al.,] stone dust [Mir sohail et al.,], Fuel oil [Hussein et al.,] etc., and considerable modification was observed. The current study aims to stabilize the soil using quarry dust as an additive.

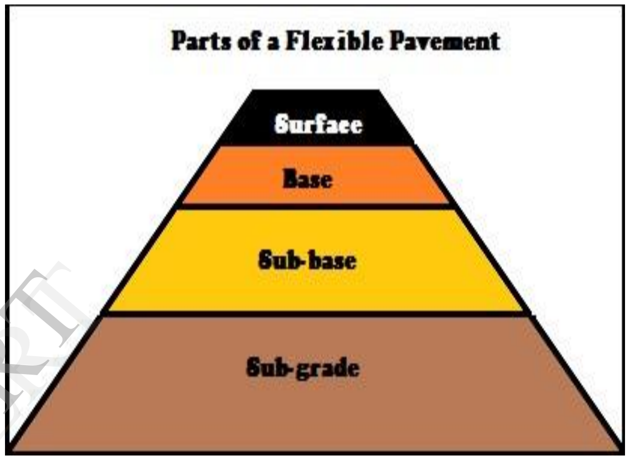

Figure. 1. **Parts of Typical Flexible Pavement**

1.1 List of Symbols used

Liquid Limit	LL
Plastic Limit	PL
Plasticity Index	PI
Non Plastic	NP
Poorly Graded Sand	SP
Maximum Dry Density	MDD
Modified Proctor Test	MPT
California Bearing Ratio	CBR
Differential Free Swell	DFS
Million Standard Axle	MSA

2. EXPERIMENTAL INVESTIGATION

Tests were conducted in laboratory mixing natural clay soil obtained from Korattur region of Chennai and Quarry Dust from the nearby aggregate quarry at Vinayagapuram. Various proportions were tried to find out the optimum percentage of quarry dust in improving the clayey soil. The details of the materials and tests conducted are furnished below.

2.1 Materials And Properties

The properties of the clayey soil and quarry dust are presented in Table.1& Table.2.

Table.1.Properties of Korattur Clay

Specific gravity, Gs	2.53
Differential Free Swell (%)	52.5
LL (%)	55
PL (%)	16
PI	39
Coefficient of uniformity (C_u)	0.85
AASHTO Classification	A-7.5
BIS Classification	CI

Table.2.Properties of Quarry Dust

Specific gravity, Gs	2.72
Absorption (%)	1.5
Bulk Density kN/m^3	1.8
Moisture Content (%)	Nil
PI	NP
Coefficient of uniformity (C_u)	0.85
AASHTO Classification	A-4
BIS Classification	SM

2.2 Tests Conducted

A series of tests were conducted to enhance and ensure the improvement of clayey soil with quarry dust in various proportions as listed below.

Table.3.Details of Tests Conducted

Name of the Test
Sieve Analysis
Atterberg limits (LL & PL)
Modified Proctor Compaction (MPC)
California Bearing Ratio (CBR)
Differential Free Swell (DFS)

2.21 Sieve Analysis

The very main purpose of conducting a sieve analysis confirming to IS 2720 (Part IV) 1970 is to optimize the proportioning of admixture with the natural soil namely clay. The well graded grain size distribution curve obtained from sieve analysis is shown in Figure 2 and 3.The proportions adopted are similar for a all the tests conducted in series

Table.4.Sieve Analysis for various proportions

Proportion	**4.75 mm**	**2.00 mm**	**0.425 mm**	**0.075 mm**
Clay 100 % + 0 % QD	98.7	98.5	84.3	50.4
Clay 90 % + 10 % QD	98.7	97.5	80.8	45.9
Clay 80 % + 20 % QD	98.6	95.9	74.5	39.7
Clay 70 % + 30 % QD	98.6	93.9	66.9	32.3
Clay 60 % + 40 % QD	98.5	92	59.9	25.4
Clay 50 % + 50 % QD	98.5	90.6	54.6	20.2
Clay 40 % + 60 % QD	98.5	89.7	51.4	17.1
Quarry Dust	98.4	89.2	49.3	15

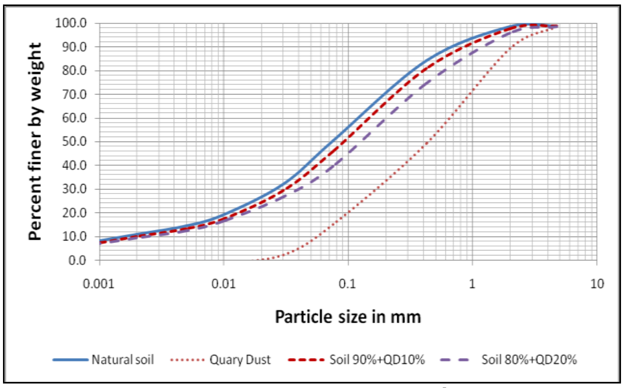

Figure. 2. Grain Size Distribution-1

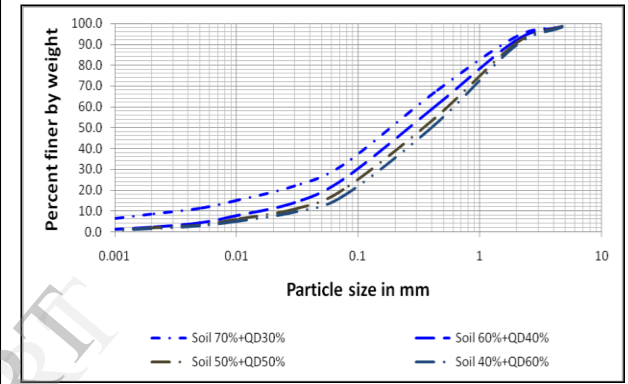

Figure. 3. Grain Size Distribution-2

2.22 Atterberg Limits

Atterberg limits say Liquid Limit and Plastic Limit are indicative limits which speak about the soil indirectly. Studies indicate that higher the Liquid Limit higher the clay content and lesser is the strength. In order to find the increase the strength of the soil the Liquid Limit and Plastic Limit tests were conducted based on Indian Standards IS 2720 (Part V) - 1970 for various proportions as indicated below. It was clearly seen that the LL and PI values showed a marked decrement till 50 % replacement of Quarry dust and beyond which no remarkable decrement was found.

Table.5. Atterberg limits test for various proportions

Proportion	**LL (%)**	**PL (%)**	**PI (%)**
Clay 100 % + 0 % QD	55.3	16.5	38.9
Clay 90 % + 10 % QD	47	17.3	29.7
Clay 80 % + 20 % QD	37.5	18	19.5
Clay 70 % + 30 % QD	30.5	19.4	11.1
Clay 60 % + 40 % QD	27.2	20.2	7
Clay 50 % + 50 % QD	24.8	20.8	4
Clay 40 % + 60 % QD	24.2	21.3	2.7

ISSN: 2278-0181
Vol. 3 Issue 9, September- 2014

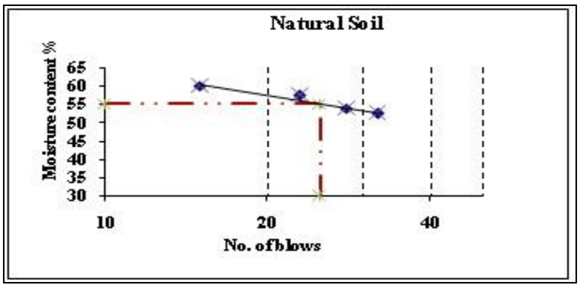

Figure. 4. LL of Natural Soil (Clay)

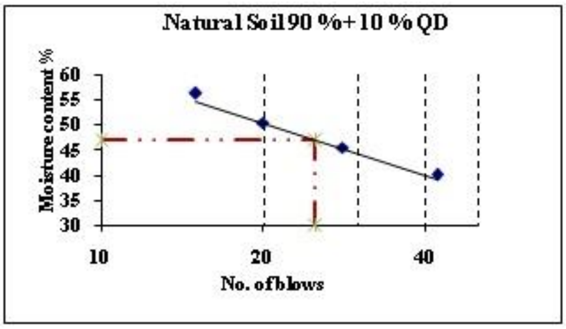

Figure. 5. LL of 90% Clay and 10% QD

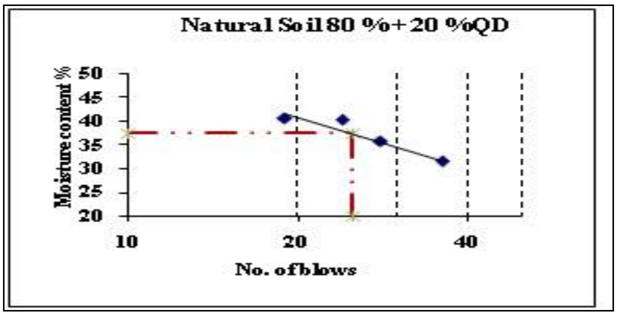

Figure.6. LL of 80% Clay and 20% QD

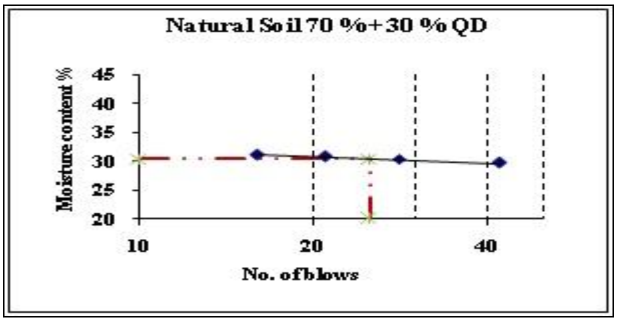

Figure.7. LL of 70% Clay and 30% QD

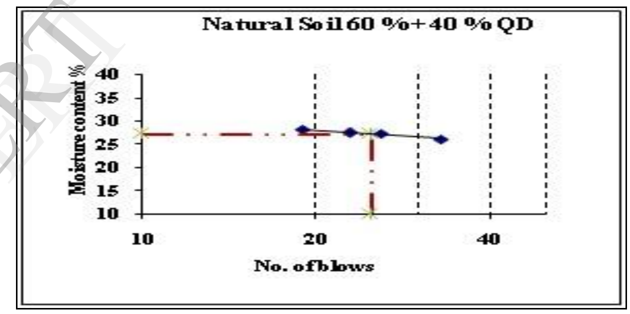

Figure.8. LL of 60% Clay and 40% QD

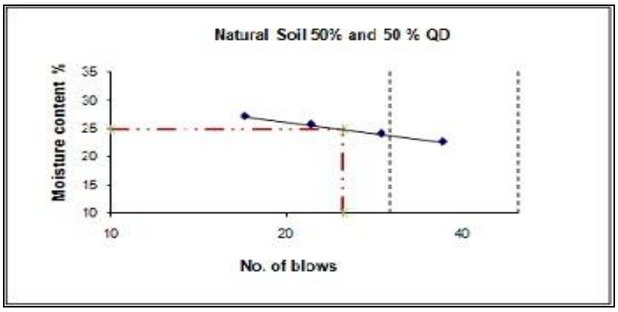

Figure.9. LL of 50% Clay and 50% QD

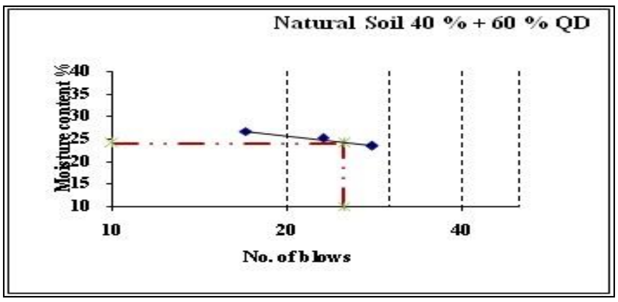

Figure.10. LL of 40% Clay and 60% QD

The test also reveals the increment of plastic limit which is in line with the previous researchers who tried to stabilize the clayey soils. The tests conducted brings to a conclusion that the replacement of quarry dust by 50% can bring down the LL values by 50 % as shown above from Fig.4 to 10.

2.23 Modified Proctor Compaction Test

Modified proctor compaction test is normally opted for higher loading applications like airport base courses and for superior quality roads like National highways. The modified proctor compaction test was conducted to show the level of improvement in density for various mix proportions. The energy applied to the soil is around 4.5 times that of a standard proctor test, higher the energy higher will the density achieved

Table.6.Modified Proctor Test for various Proportions

Proportion	MDD (g/cc)	OMC (%)
Clay 100 % + 0 % QD	1.87	12.70
Clay 90 % + 10 % QD	1.89	12.20
Clay 80 % + 20 % QD	1.91	10.00
Clay 70 % + 30 % QD	1.94	9.30
Clay 60 % + 40 % QD	1.96	9.60
Clay 50 % + 50 % QD	2.01	8.85
Clay 40 % + 60 % QD	2.00	8.75

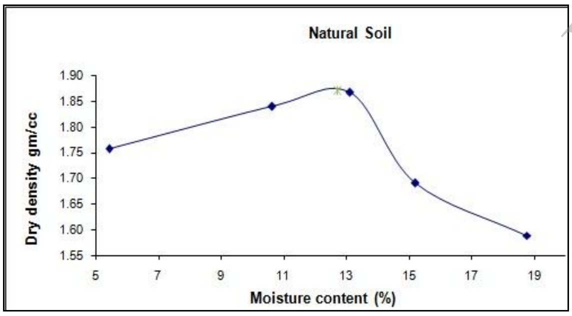

Figure.11. MPT for Natural Soil

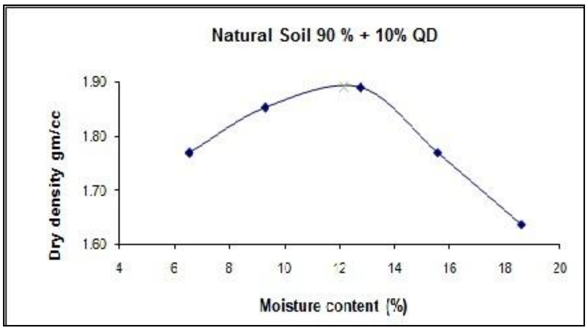

Figure.12. MPT for Natural Soil 90% and 10 % QD

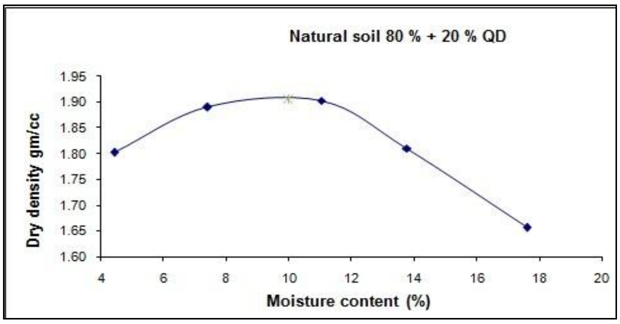

Figure.13. MPT for Natural Soil 80% and 20 % QD

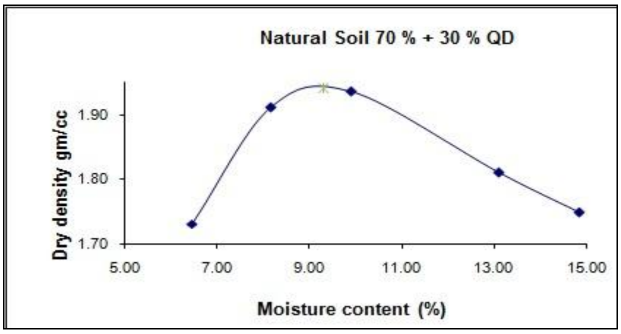

Figure.14. MPT for Natural Soil 70% and 30 % QD

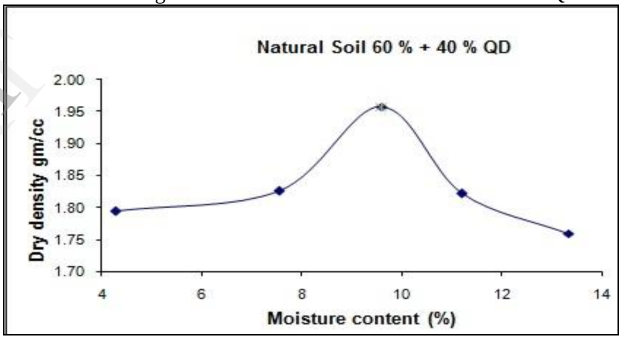

Figure.15. MPT for Natural Soil 60% and 40 % QD

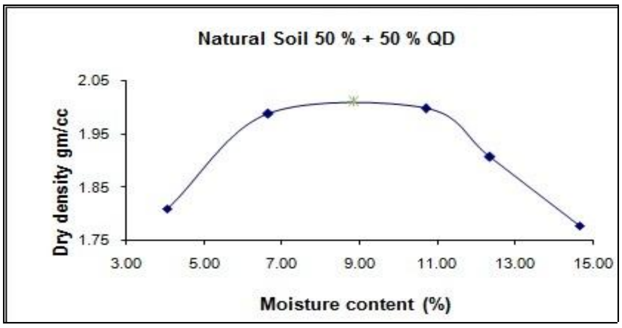

Figure.16. MPT for Natural Soil 50% and 50 % QD

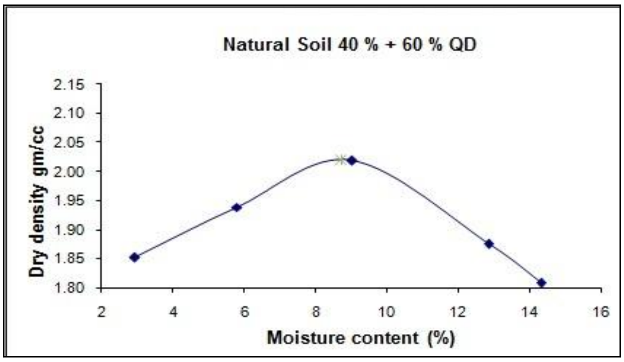

Figure.17. MPT for Natural Soil 40% and 60 % QD

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 9, September- 2014

Similar variation of results are seen in modified proctor compaction test which are in line with Atterberg limits as shown from Figure.11 to 17. The improvement of dry density and optimum moisture content is not appreciable beyond 50 % replacement.

2.24 CALIFORNIA BEARING RATIO & DFS TEST

California Bearing Ratio (CBR) test is a penetration test wherein a standard piston, having an area of 50 mm diameter, is used to penetrate the soil at a standard rate of 1.25 mm/minute. The pressure up to a penetration of 12.5 mm and it's ratio to the bearing value of a standard crushed rock is termed as the CBR.

In most cases, CBR decreases as the penetration increases. The ratio at 2.5 mm penetration is used as the CBR. In some case, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at5 mm should be used. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions.

$$\text{CBR} = \frac{\text{Load carried by specimen}}{\text{Load carried by standard specimen}} \times 100$$

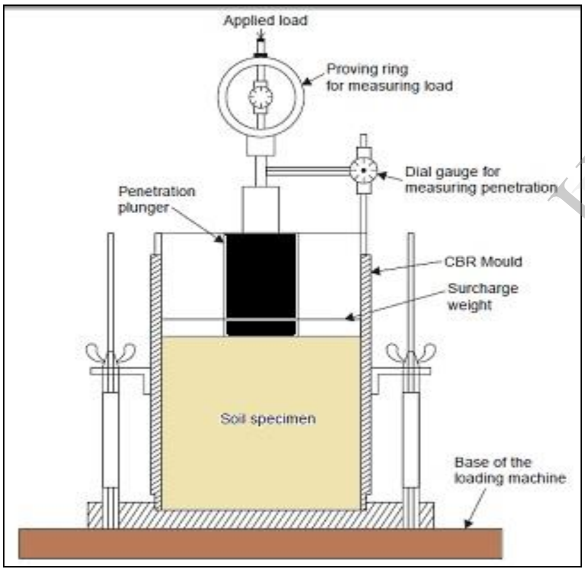

Figure.18. CBR Apparatus

Differential free swell test (DFS) is conducted to identify the quantum of swell in the soft soils by pouring 10 grams of soil passing through 425μ sieve in a 100 cc glass cylinder one filled with water and other with kerosene. Kerosene being a non-polar liquid does not cause any volume change in the soil. After 24 hours the volumes of the soil in the two cylinders are measured and Differential free swell is obtained.

$$\text{DFS} = \frac{\text{Soil Volume in water} - \text{Soil volume in kerosene}}{\text{Soil volume in kerosene}} \times 100$$

Both the tests were conducted in accordance with the Indian Standards and with the same proportions as that of the previous tests. The results are tabulated in table 6 and figures are represented from Fig.18 to 23.

Table.7.CBR & DFS Test for various Proportions

Proportion	CBR (%)	DFS (%)
Clay 100 % + 0 % QD	4.9	58.70
Clay 90 % + 10 % QD	7.08	34.20
Clay 80 % + 20 % QD	8.52	29.07
Clay 70 % + 30 % QD	11.48	22.30
Clay 60 % + 40 % QD	15.65	19.60
Clay 50 % + 50 % QD	20.76	18.85
Clay 40 % + 60 % QD	22.84	17.75

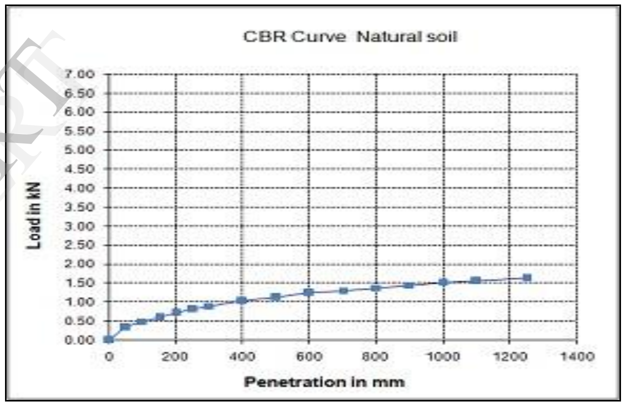

Figure.19. CBR Curve for Natural Soil

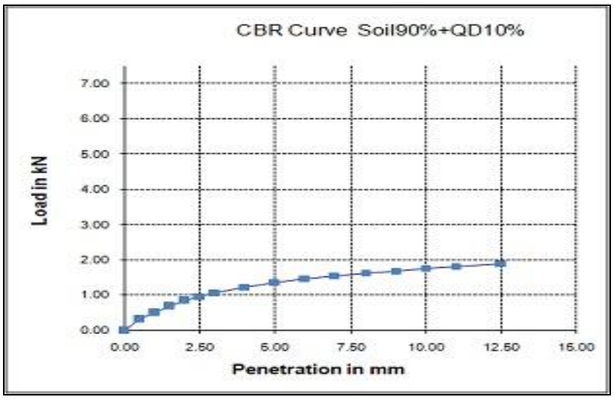

Figure.20.CBR Curve for Natural Soil 90% and 10 % QD

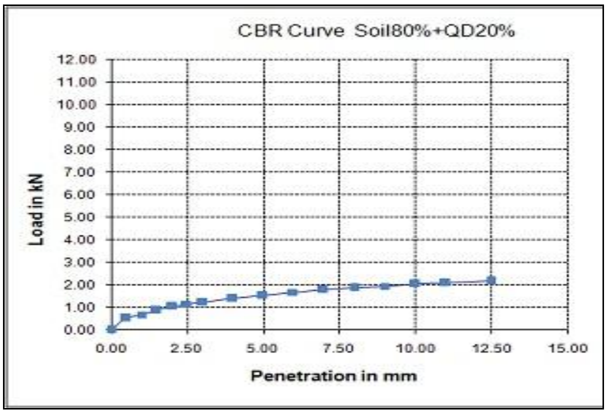

Figure.21.CBR Curve for Natural Soil 80% and 20 % QD

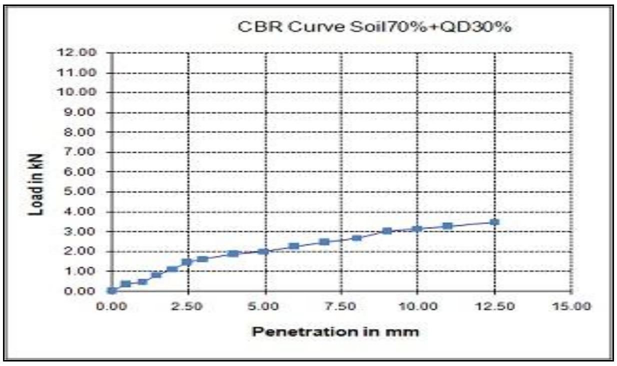

Figure.22.CBR Curve for Natural Soil 70% and 30 % QD

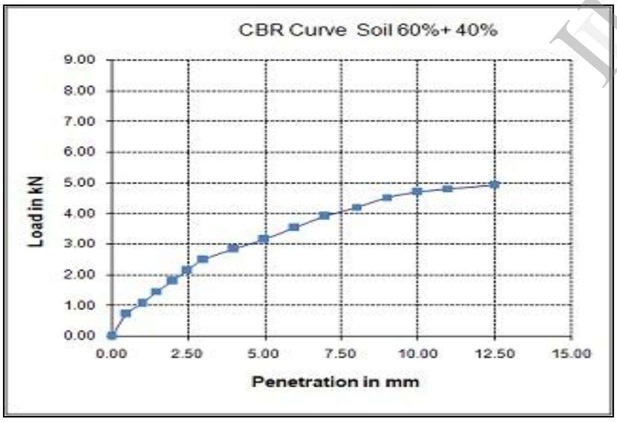

Figure.23.CBR Curve for Natural Soil 60% and 40 % QD

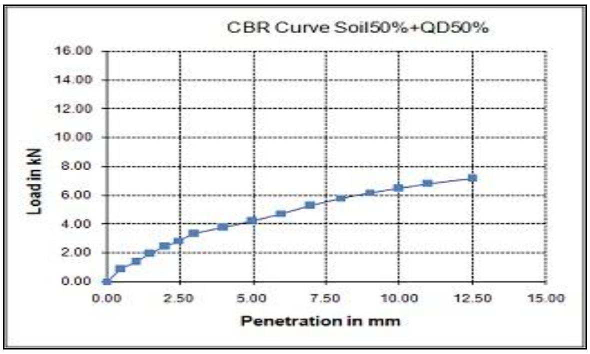

Figure.24 CBR Curve for Natural Soil 50% and 50 % QD

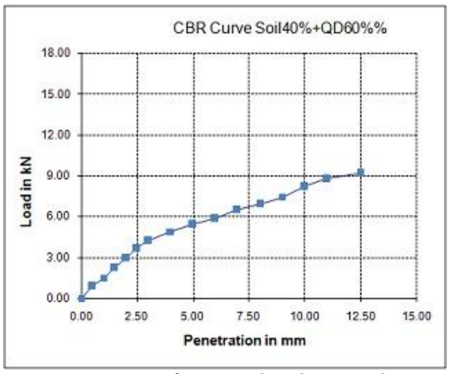

Figure.25.CBR Curve for Natural Soil 40% and 60 % QD

The results obtained shows a gradual increment in the CBR value from 5 % to 22 % as shown from Figure.19 to 25 with the increase in the proportion of quarry dust. As it wouldn't be economically feasible in the site conditions to adopt more than 60 % replacement of the original soil with quarry dust, the test proportions were stopped for the above mentioned proportion of QD.

According to IRC 37-2001,the subgrade should have a minimum CBR value of 5.9% to provide a pavement of total thickness 615 mm for 10 MSA traffic. Hence a minimum of 10 % replacement by quarry dust is required for laying a flexible pavement of thickness 615 mm. Further addition of quarry dust till 30 % will effectively reduce the pavement thickness to 540 mm which will reduce the cost of laying the pavement to a substantial rate.

The differential free swell values decrease at a constant rate by the addition of quarry dust, it is observed that no appreciable swelling takes place beyond 30 % addition of QD.

As per IS 2911 part 3 (1980) if the soil has to be used in the top 500 mm subgrade the DFS value should lie between 35 to 50 and hence mere addition of 10 % quarry dust will arrest the swelling substantially in using the korattur clay soil as a subgrade material.

3 CONCLUSIONS

The study on stabilizing the locally available clayey soil in korattur by quarry dust with the support of series of laboratory investigations in specific arrived at the following conclusions.

1. Substantial improvement in quality of korattur clay soil is observed with addition of Quarry Dust in laying flexible pavements.
2. The addition of quarry dust not only arrests the swelling nature but also increases the CBR value which in turn reduces the thickness of pavement.

3. The total pavement thickness can be reduced from 615 mm to 540 mm by replacement of clayey soil with 30 % Quarry Dust.
4. Minimum of 10 % replacement in clayey soil with quarry dust is required to arrest the swelling nature of the soil.
5. As a whole the quantum of replacement of quarry dust is found to be in the range of 40% to 50 % in laying road pavements for the in-situ korattur clayey soil which is marginally higher.
6. For economical considerations and for laying local pavements inside streets and villages 30% replacement of clayey soil can be sorted.
7. Further detailed investigations are necessary in finding out the rate of strength improvement in clay soil by adding quarry dust by conducting shear strength tests.

REFERENCES

[1] 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, Vol. 28(4), Paper ID GTJ11768, 391-400

[2] Praveen Kumar, Satish Chandra, and Vishal, R. (2006). Comparative study of different subbase materials. J. Mat. in Civ. Engrg. Vol.18(4), 576-580I.S. Jacobs and C.P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G.T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271-350.

[3] Phanikumar, B.R. and Sharma, R.S. (2004). Effect of flyash on engineering properties of expansive soil, Journal of Geotechnical and Geoenvironmental Engineering Vol. 130(7), 764-767.

[4] Asmidar, A., Bujang, B. K., Azlan, A., Evaluation, selection and assessment of guidelines for chemical stabilization of tropical residual soils, American Journal of Environmental Sciences, Vol. 4, No. 4, p. 303 – 309, November 2008.

[5] Hussein Yousif., Jianlin Ma (2011).,Gypseous soil improvement, Electronic Journal of Geotechnical Engineering Vol. 16 Bundle H, 851-862

[6] Deepa Ra.B (2013).,Stabilization of pavement material using waste brick kiln dust, International Journal of Engineering Research and Technology,Vol.2 Issue 4,p.1684-1691.

[7] Anonymous:IS: 2720 (Part 16) – 1987. Laboratory determination of CBR, Bureau of Indian Standards.

[8] Anonymous: IS: 2720 (Part 8) - 1983. Determination of water content – dry density relation using heavy compaction, Bureau of Indian Standards