

Soil Stabilization Using Nano-Materials for Rural Roads—A Case Study

S.Anwar Hussain

Executive Engineer, LSGD Division, Thiruvananthapuram, Kerala, India

ABSTRACT: The paper presents a study on stabilization of different types of soils using nano-chemicals. Nano-chemicals are nanotechnology based products which can provide solutions to moisture and bonding issues in pavements. Addition of nanoparticles as an external factor to soil will result in soil manipulation at atomic or molecular level and it influences the strength, permeability indices and resistance properties of soil. Nanotechnology is a reformed mode which can address the rising concern of poor quality roads. This paper presents a case study of trial section along sector 19, Gandhinagar, Gujarat, where the field in situ densities, CBR and Benkelman Beam Deflection (BBD) analysis was carried out to determine the in situ stiffness of the cement stabilized road base material with nanochemicals. It was an expansive soil entirely different from the normal well drained soil in their morphological, chemical and physical characteristics. Another study section at Kuruvilakam road under Pothencode Block involves the stabilization of soil with the addition of cement ranging from 1% and spray application of organosilane solution mixed with nano polymer. Experimental studies indicate that mixing of nanochemicals with cement in soil reduces the plasticity index and increases the compaction characteristics, CBR and other strength parameters like UCS.

I. INTRODUCTION

Roads are a vital component in nation building and one of the most effective modes to establish socio-economic and political network. For a country like India, blessed with robust monsoons, moisture becomes an enemy of roads. Ingress of water in the rainy season weakens the roads soil base. Strength of soil is an important factor to be included in design considerations of roads. Particularly, clayey soils may cause severe problems in pavement design due to uncertainties associated with their performance. Cement/lime treatment has become an accepted method for increasing the strength and durability of soils. However it is ineffective in certain conditions and large scale use of cement/lime may leads to high cost.

Nano-chemicals are nanotechnology based products which can provide solutions to moisture and bonding issues in pavements. Addition of nanoparticles as an external factor to soil will result in soil manipulation at atomic or molecular level and it influences the strength, permeability indices and resistance properties of soil. Nanotechnology is a reformed mode which can address the rising concern of poor quality roads.

Organosilanenanochemical which has been examined at study site is a nanotechnology based product manufactured by Zydex Industries, Gujarat. It is water soluble, ultra violet and heat stable, reactive soil modifier. It improves the frictional value, reduces water permeability and maintains breathability of the soil layer. It forms Si-O-Si bonded nanosiliconize surfaces in soil by converting water loving Silanol groups to water repellent Alkyl Siloxane groups. Organosilanenanochemical is environmental friendly as it allows the use of in situ soil and conserves limiting resources like aggregates and bitumen.

This paper presents a case study of trial section along sector 19, Gandhinagar, Gujarat, where the field in situ densities, CBR and Benkelman Beam Deflection (BBD) analysis was carried out to determine the in situ stiffness of the cement stabilized road base material with nanochemicals. It was an expansive soil entirely different from the normal well drained soil in their morphological, chemical and physical characteristics. Another study section at Kuruvilakam road under Pothencode block involves the stabilization of soil with the addition of cement ranging from 1% and spray application of organosilane solution mixed with nano polymer. Experimental studies indicate that mixing of nanochemicals with cement in soil reduces the plasticity index and increases the compaction characteristics, CBR and other strength parameters like UCS.

The replacement of Combined Granular Base/Sub-base layer with a stabilized soil layer (Stabilisation with Terrasil + Cement) is technically feasible under the enhanced CBR of subgrade soils. The thickness of the stabilized soil that to be

Organized by

Department of CSE, MCA &CE, Mohandas College of Engineering and Technology, Thiruvananthapuram, Kerala, India

provided in lieu of WBM/GSB layers is technical justified based on the Odemark's theory of Equivalent Layer Thickness. The composite modulus of the WBM/GSB is related to the modulus of the stabilized soil, which means comparison of the layer stiffness based on the unique thickness of the layer. Hence it can be concluded that the stabilization using cement with nanochemicals is an efficient and economical way of stabilizing the base layers and replacing WBM/WMM and GSB layers of road construction.

II. MATERIALS

Soil: The soil at site under examination is brown in shading made of fine particles (category CL) and is obtained from sector 19, Gandhinagar, Gujarat. Soil available at Pothencode block is of red lateritic gravel.

Cement: Ordinary Portland Cement (OPC) of Grade 43 was used for stabilization of the selected soil.

Organosilane (Terrasil): The substance used at the site to balance out the clayey soil was Terrasil produced by Zydex Industries, Gujarat, possessing ingredients Hydroxyalkyl – alkoxy – alkylsilyl compounds (65 – 70 %), Benzyl alcohol (25 – 27 %) and Ethylene glycol (3 – 5 %). It is water soluble, easy to apply, nanotechnology based Organosilane compound. It is a UV & heat stable reactive soil modifier to stabilize and waterproof soil subgrade. It is a green technology enabling minimal use of aggregates. It reacts with water loving silanol groups of sand, silt, clay, and aggregates to convert it to highly stable water repellent alkylsiloxane bonds and forms a breathable in-situ membrane. It resolves the critical sub-surface issues. The untreated soil surface silicate structure and treated soil creating a molecular level hydrophobic membrane is shown in Figure 1.

Polymer (Zycobond): It is acrylic co-polymer dispersion for the soil particles and imparting resistance to soil erosion and dust control. It is blended with organosilane and showered on compacted soils. It enhances the quality of soil layer, controls soil disintegration, quick drying of soil layers/earth road after downpours and thus it helps in reducing maintenance cost.

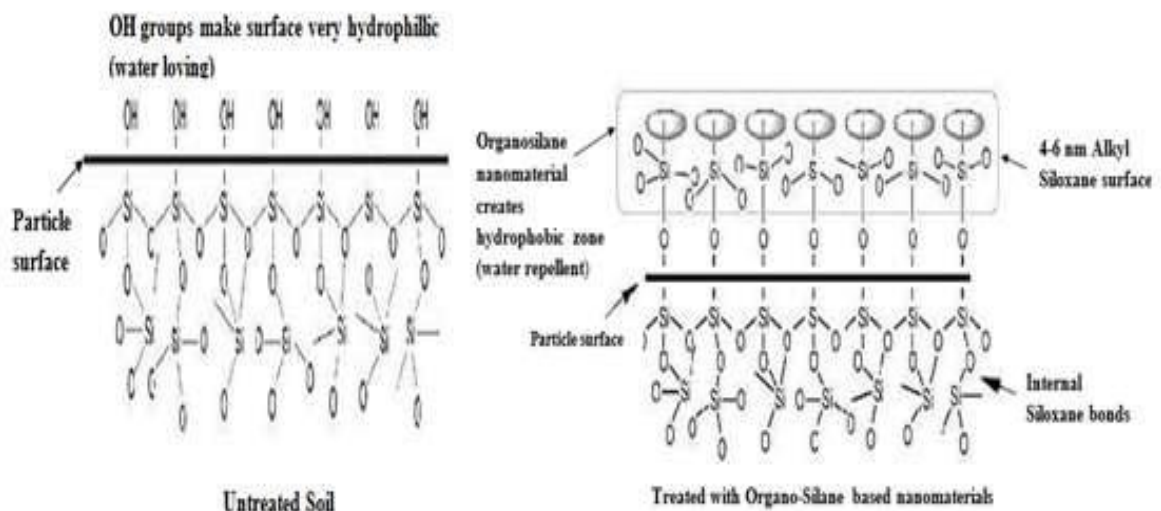


Fig 1. Untreated soil surface silicate structure and Treated soil surface silicate structure

Organized by

Department of CSE, MCA &CE, Mohandas College of Engineering and Technology, Thiruvananthapuram, Kerala, India

III. SOIL STABILISATION USING ORGANO SILANE NANOMATERIALS AND CEMENT

Organosilane solution mixed with nanopolymer was prepared by filling the tanker with water, simultaneously and complete mixing was done. The water quantity per cubic metre of soil was purely the function of OMC, in-situ moisture and soil density. It is independent of dosage of nanomaterials.

The dosage of organosilane was 0.6 kg/m³ and polymer was 0.6 kg/m³ and cement 3%. This means that 0.6 kg of organosilane and 0.6 kg polymer will be mixed with (OMC minus in situ moisture) the quantity of water required for compaction and make the solution adequate to treat 1 m³ of soil.

The spread soil was excavated from the borrow area and pulverised the laid loose soil to make it finer. The spray was done with organosilane solution mixed with polymer and scarified again to get proper mixing. The treated soil was then carried to the site and spreaded at site. Immediately cement was spreaded on the wet soil and mixed well using rotovator. Then the soil was compacted within 1-2 hours. Immediately after compaction, a 50 mm thick aggregate (size 10 mm – 19 mm) layer was laid and compacted immediately with a roller compactor and ensured that the aggregates were fully embedded into the treated soil matrix. Finally, another organosilane solution mixed with polymer with the ratio of 1: 0.5: 200 (Organosilane 1 kg : Polymer 0.5 kg : Water 200 liter) was prepared and sprayed on the surface at the rate of 2 liter per m².

IV. LABORATORY INVESTIGATION RESULTS

From the CRR I study it was observed that, cement stabilization is used to modify soil properties along with small quantities of nanomaterials. The addition of organosilane eliminates capillary rise and water ingress from top, and reduces water permeability. Stabilization has been done using 3% cement and organosilane 0.75 kg/cum of soil. Results of improvement in engineering properties of soil for use in sub-base and base course construction are as in Table. 1.

Table 1: Laboratory Test Summary

Sr. No	Parameters	Measure	Soil w/o additive	Soil + Cement 3%	Soil + Silane 0.75 kg/m ³ + polymer 0.75 kg/m ³ + Cement 3%
1	CBR	%	7	67	125
		% Improvement	-	857%	1685%
2	UCS	MPa	0.27	1.02	2.43
		% Improvement	-	278%	800%
3	Durability (Wet – Dry Cycles)	No. of cycles	0	4	12
		IS : 4332 (Part 4)	Fails	Fails	Passes (Simulates 20 years life)

Sr No.	Parameters	Unit	Point 1 (Chainage 45m)	Point 2 (Chainage 110m)	Test Code
1	Moisture content	%	2.0	1.00	IS 2720 Part 28
2	Dry Density	gm/cc	2.06	2.12	IS 2720 Part 28
3	DCPT: penetration (Average)	mm/blow	5.9	4.16	ASTM D6951-09
4	In-situ CBR based on DCPT	%	39.96	59.1	IRC 37-2012
5	BBD	mm	1.12		IRC 81:1997

Table 2. Field Test Summary

Organized by

Department of CSE, MCA &CE, Mohandas College of Engineering and Technology, Thiruvananthapuram, Kerala, India

V. FIELD MONITORING PROGRAMME

A testing program was done for the purpose of monitoring the quality and performance of the stabilized pavement in field at various stages, during and after the nanochemical stabilised based layer construction. The testing comprised density measurements, Dynamic Cone Penetration Test (DCPT), In situ CBR based on DCPT and Benkelman Beam Deflection (BBD). Laboratory tests on the organosilane stabilised soil specimens were also done. Density measurements were made after compaction using sand replacement test. The density results were used to ensure the stabilised layer had achieved the minimum 94% relative density during the stabilisation work.

VI. CONCLUSIONS

A pavement section of 1 km in length on the Sector 19, Gandhinagar, Gujarat and 800 m in Kuruvilakam road in Pothencode has been constructed by strengthening the existing granular road base using organosilane nanomaterial and cement stabilization. The performance of the completed pavement was investigated through DCPT and BBD testing. The use of nanomaterial stabilized base leads to a significant improvement in the structural capacity of the pavement and it can replace the combined granular base/sub-base layer with a stabilized soil layer (Stabilization with organosilane nanomaterial + Cement). From the CRRRI laboratory reports it was observed that the behaviour of soil changes with the addition of silane. The amount of stabilizer required for appreciable stabilization depends on the characteristics of soil. The following conclusions can be drawn from the results, such as:

- It is observed that organosilane works well with the combination of cement and makes the soil stiff, so that in low traffic area stabilized gravel road can be constructed.
- It is observed that CBR values increase 1700 times with the combination of cement, organosilane & nanopolymer.
- It is observed that UCS strength increases with increase in dosage of organosilane and curing period.
- In durability tests, the samples with cement and organosilane passed all the wet and dry cycles, whereas other soil samples could not withstand the WD cycles.

This signifies that such stabilization technologies optimize the potential improvements to strength of pavement foundation thereby increasing the load carrying capacity of pavement. From economy point of view benefit associated with the utilisation of organosilane nanomaterials with cement is attractive and supports the sustainable development in road construction. The assessment and suitability of construction procedure of roads with nanomaterial stabilised soil was done. The test results were verified and the design parameters such as the in-situ CBR and soil stiffness were achieved at site. Monitoring works carried out during these trials will allow any initial problems to be identified and rectified before commencing the planned full scale stabilisation work in Ponnudi Trivandrum. It will help to give cheap and cost effective road connectivity to the nearby villages. It can be black topped directly after two years to improve the riding quality.

REFERENCES

- [1] Khusboo Arora and P.K. Jain (2016), Studies on Use Of Nano-Materials and Cement for Improvement of Soil in Rural Roads Construction. CSIR-Central Road Research Institute, New Delhi 11002, India.
- [2] G. W. K. Chai, E. Y. N. Oh and A. S. Balasubramaniam (2004), In-Situ Stabilization of Road Base Using Cement - A Case Study in Malaysia. School of Engineering, Griffith University Gold Coast Campus, Gold Coast, Queensland 9726, Australia.
- [3] E A Basha, R Hashim, H B Mahmud and A S Muntohar (2004), Stabilization of residual soil with rice husk ash and cement. Construction and building materials, ELSEVIER Science, 19, pp 448-453.
- [4] Satish Chandra M N, Viladkar and Prashant P Nagrale (2008), Mechanistic Approach for Fiber-Reinforced Flexible Pavements, Journal of Transportation Engineering, ASCE, Vol. 134, No. 1, pp 15-23.
- [5] Mahsen Mahawish (2013), Chemical Stabilization of Gypseous Subgrade Soils for Road Construction in Iraq, Journal of Engineering and Development, Vol. 17, No.4, pp 1-13.
- [6] Masashi Kamon and Supakij Nontananandh (1991), combining industrial wastes with lime for soil stabilization, Geotech Engrg, Vol 117, pp 1-17.
- [7] Nandan A Patel and C. B. Mishra (2014), Improvement of Inorganic Clayey Soil using Cement Additive, International Journal of Current Engineering and Technology, Vol.4, No.6, pp. 4266-4269.
- [8] Nandan A. Patel and C. B. Mishra Parmar E. K., Gautam S. B. (2015), Subgrade Soil Stabilization using Chemical Additives. , International Journal of Current Engineering and Technology, pp 1089-1095
- [9] T. Thyagara, Sudhakar M Rao, P Sai Suresh and U Salini. (2012). Laboratory Studies on Stabilization of an Expansive Soil by Lime Precipitation Technique, Journal of Materials in Civil Engineering, ASCE, 24(8), pp 1067-1075.