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SOIL MINERALOGY AND COMPACTION TECHNIQUES FOR IMPROVING FOUNDATIONS STABILITY

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ABSTRACT: The experimental and computational methods have been applied for assessing mixed soil characteristics. To enhancement bearing capacity of the mixed soil the mineralogy and soil mechanic testing techniques have been used. The result indicated that for improving a mixed soil characteristics it has to be embedded with appropriate minerals, and due to presence of Pyrophyllite mineral, the negative correlation between compaction technique with enhancement of soil mechanical properties has been observed, it could be suggested that in landslide mitigation or any subsoil improvement if Pyrophyllite mineral presence, the compaction technique could not be apply, it will result reverse, and it is observed that gathering Illite, Muscovite and Sauconite in a soil lead to achieving maximum level of density, and also some other minerals may have same affect on mixed soil compaction that is required to be more investigate.
KEYWORDS: Soil Science; Construction Material; Mineralogy; Bearing Capacity

❖ INTRODUCTION

Soil mixing has been successfully applied for liquefaction mitigation, steel reinforced retaining walls, groundwater cutoff walls, and stabilization of contaminated soils. Applications of this technology have recently been expanded. Such applications have included settlement control of soils, slope stabilization and formation of composite gravity structures. In slope stability applications, soil mixing could improve the overall shear strength of the soil formation to adequately increase the factor of safety [Kenneth B. Andromalos et al, 2000 & Bahner, Eric W, 2000 & Bergado D.T. et al., 1990, & Lin K.Q. and Wong I.H, 1999& & Liver Norman L et al, 1954 & Nicholson P.J et al, 1998 & Ryan Christopher R et al, 1989]. There is an investigation on the south west area of Cyprus which has a long history of slope instability problems. The location and extent of these landslides has been influenced by ground morphology, mineralogy and geological structure [J. Hadjigeorgiou et al, 2006]. A study has been conducted, it is revealed slope instability causing landslides, and a major geologic hazard, and it is a risk common to most regions [Sasan Mafian, 2009]. The mineralogy and mechanical properties of 9 mixed soils under different conditions have been analyzed, the authors made an attempt to evaluate the affect of moisture and compaction technique in changing soil mechanical properties based on soil mineralogy.

❖ METHODOLOGY AND EXPERIMENTS

A number of theoretical and computational studies have been performed by various researchers to determine the bearing capacity of foundations [Sarma & Iossifelis 1990; Budhu & Al-Karni, 1993; Richards *et al.* 1993; Dormieux & Pecker, 1995; Soubra 1997, 1999; Zhu 2000; Kumar & Mohan Rao 2002, 2003; Kumar & Kumar 2003]. Form these different existing studies it is understood that the ultimate bearing capacity of the foundations decreases continuously with a changing in the soil characteristics. On the other hand, not many studies have been made to assess the bearing capacity of foundations in the considering soil mineralogy. It is also not known from the available literature, either from any experimental study or from the theory, about the effect of the mineralogy on the foundations capability. This is the motive of the present research work. It is aimed to perform a series of the modeling studies on assessing the behavior of the foundations placed on a soil with different mineralogy. The purpose of the entire research exercise would be to (i) predict the response of the mixed soil when it is improved by compaction technique, and (ii) formulate some useful guidelines to design the foundations in the presence of different minerals.

The material for developing mixed soil models indicated in the table, and the safe bearing capacity, angle of friction, unit weight and cohesion of mixed soils sample have been used, and the XRD results of six soil samples has also been used as soil mineralogy investigation for assessing affect of moisture and compaction test in changing soil mechanical properties.

Table 1. Mixed soil models [Abdoullah Namdar, 2009]

Model No	% of Red Soil	% of Sand	% of Gravel 4.75 mm	% of Gravel 2 mm	% of Black Soil	% of Green Soil	% of Dark Brown Soil	% of Yellow Soil	% of Light Brown Soil
1	100	0	0	0	0	0	0	0	0
2	55	45	0	0	0	0	0	0	0
3	55	0	45	0	0	0	0	0	0
4	55	0	0	45	0	0	0	0	0
5	55	0	0	0	45	0	0	0	0
6	55	0	0	0	0	45	0	0	0
7	55	0	0	0	0	0	45	0	0
8	55	0	0	0	0	0	0	45	0
9	55	0	0	0	0	0	0	0	45

❖ RESULTS AND DISCUSSION. SOIL MINERALOGY AND STRUCTURE ATOMIC

X-ray powder diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions. The analyzed material is finely ground, homogenized, and average bulk composition is determined [web site].

To evaluating mineralogy of a soil, three top minerals intensity presented in the fig 1.a-f selected for analysis of a soil mineralogy characteristics based on Bragg's Law, the maximum intensity is 100% and minimum of that could be any amount is indicated in the table 2.

The most widespread use of x-ray powder diffraction is to determination of the crystal structure of identified materials and identification and structural analysis of clay minerals. In the X-ray method diffraction angle could be find by adopting Bragg's Law which is $n\lambda = 2d \sin\theta$, where n = an integer = 1, λ = the wavelength of the X-rays = 1.5406 A°, d = the interplanar spacing generating the diffraction, θ = the diffraction angle.

The "angle" of the diffraction (recorded as 2θ by convention) is related to the inter-planar spacing, d, by the Bragg law, and the intensity of the diffraction maximum is related to the strength of those diffractions in the specimen. The angles and intensities of diffractions are recorded electronically using a detector, electronics and specialized software resulting in a plot of 2θ (horizontal axis) vs. intensity (vertical axis) for the specimen [James R. Connolly, 2007].Q

Table 2. XRD experimental data of different soils [Abdoullah Namdar, 2009]

Soil Type	θ [°]	d [A°]	Intensity (ops)	I/I_0 [%]
Red soil	13.35	3.3360	2919	100
	14.02	3.1796	864	30
	25.11	1.8152	846	29
Black soil	13.29	3.3508	9312	100
	10.4	4.2670	2297	25
	25.04	1.8199	1316	15
Yellow soil	13.34	3.3385	13545	100
	16.33	2.7396	7551	56
	21.5	2.1017	3763	28
Light brown	13.34	3.3385	5937	100
	13.99	3.1862	2708	46
	10.44	4.2509	1201	21
Dark brown	15.48	2.8860	2646	100
	14.26	3.1271	1882	72
	12.33	3.6072	1770	67
Green	13.94	3.1974	2910	100
	13.31	3.3459	2573	89
	17.72	2.5308	1301	45

Table 3. Mineral of different soils identify by X-ray experimental [Abdoullah Namdar, 2009]

Soil Name	Minerals in the soil sample
Red soil	Quartz, Illite, Muscovite, Saponite, Sauconite and Carbonate - Fluorapatite
Black soil	Quartz, Pyrophyllite, Carbonate- Fluorapatite and Orthochamosite
Yellow soil	Quartz, Brucite, Clinochlore and Sandoite
Light brown soil	Quartz and Carbonate
Dark brown soil	Nacrite, Odinite, Amesite, Chamosite and Biotite
Green soil	Quartz, Cancrisilite, Chamosite, Orthochamosite and Brucite

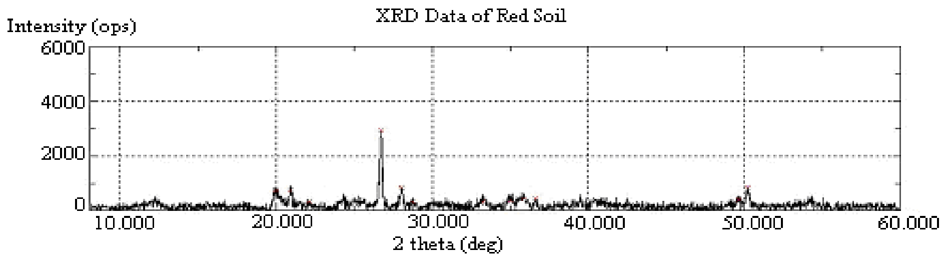

Fig.1.a. XRD Data of Red Soil [Abdoullah Namdar, 2009]

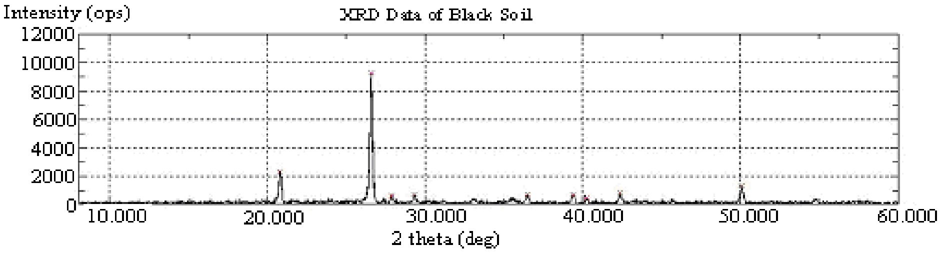

Fig.1.b. XRD Data of Black Soil [Abdoullah Namdar, 2009]

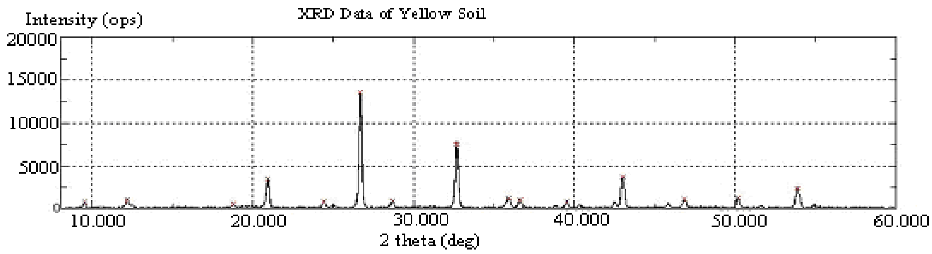

Fig.1.c. XRD Data of Yellow Soil [Abdoullah Namdar, 2009]

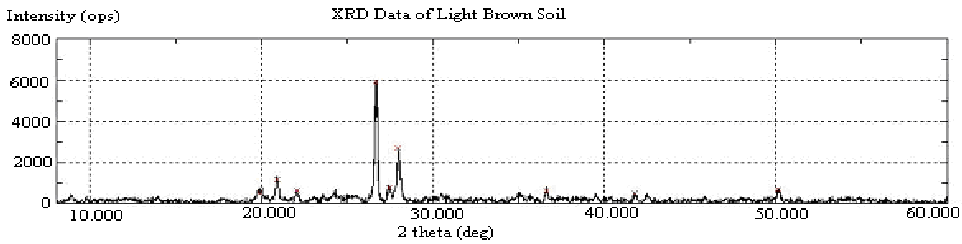

Fig.1.d. XRD Data of Light Brown Soil [Abdoullah Namdar, 2009]

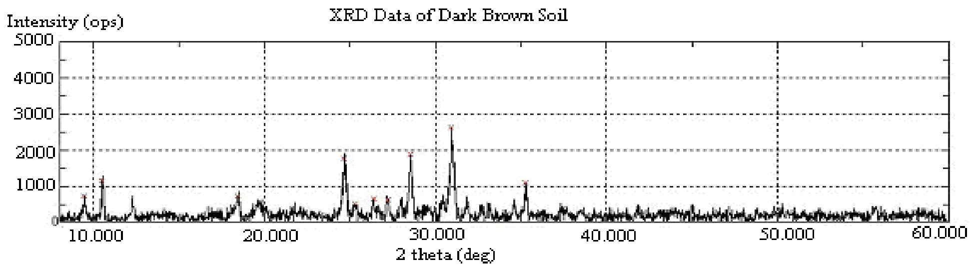

Fig.1.e. XRD Data of Dark Brown Soil [Abdoullah Namdar, 2009]

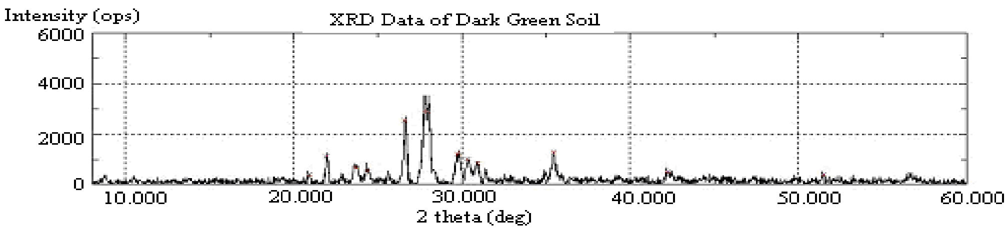

Fig.1.f. XRD Data of Dark Green Soil [Abdoullah Namdar, 2009]

The peaks have been indexed and minerals present in the soils were identified by use of the standard D-spacing and mineral intensity (Table 2 and Fig 1a-f). The important minerals present in the soils are quartz, muscovite, biotite, carbonates and fluorapatite. Clay minerals like illite, saponite, sauconite, pyrophyllite, orthochamosite, brucite, clinochlore, nacrite, odinite, amesite, chamosite, cancrisilite, chamosite and orthochamosite were also present as minor constituents, only the red soil has considerable amount of clay minerals, where as the remaining other soils have meager concentrations (Table 3) [Abdoullah Namdar, 2009].

❖ SOIL MINERALOGY AND MECHANICAL PROPERTIES CORRELATION

The nature of soil mineralogy is one of the main factors at play in level of soil liquid limit and plastic limit. It has direct effect on increasing soil bearing capacity, reduction of unsustainable deformation, differential settlement and increasing stability of soil foundation [Abdoullah Namdar, 2009].

There are several codes for improvement ground have been used [Liew Shaw-Shong, 2005]. It could be also find increasing soil ultimate bearing capacity using mixed soil in evaluation and employed of soil mineralogy concept for better ground improvement (Table 4-8), it may vary considerably from one site to another. It increased site stability against natural phenomena, such as landslide.

Table 4. Experiments Results When Soil Is in Loose 0% Moisture Condition [Abdoullah Namdar, 2009]

Model No	Moisture (%)	γ (KN/m^3)	Φ Degree	C (KN/m^2)	S. B. C (KN/m^2)
1	0	11.808	38	0	701.55
2	0	12.54	35	10	699.82
3	0	13.93	36.5	14	1082.95
4	0	12.71	42	0	1522.62
5	0	11.5	37	12	972.18
6	0	12.11	36	0	529.09
7	0	13.26	32	0	329.73
8	0	11.38	35	0	407.78
9	0	11.2	37	0	577.32

Table 5. Experiments Results When Soil Is under 3% Condition [Abdoullah Namdar, 2009]

Model No	Moisture (%)	γ (KN/m^3)	Φ Degree	C (KN/m^2)	S. B. C (KN/m^2)
1	3	10.84	30	2	236.21
2	3	11.5	35	0	412.08
3	3	13.32	36	10	865.26
4	3	12.23	38	6	936.03
5	3	11.8	36	4	628.87
6	3	10.9	34	0	336.99
7	3	11.8	32	0	293.43
8	3	12.23	32	0	304.12
9	3	12.71	32	0	316

Table 6. Experiments Results When under 6% Soil Is under Condition [Abdoullah Namdar, 2009]

Model No	Moisture (%)	γ (KN/m^3)	Φ Degree	C (KN/m^2)	S. B. C (KN/m^2)
1	6	10.54	25	6	176.81
2	6	9.99	31	0	218.20
3	6	12.23	31	20	622.89
4	6	11.81	37	0	735.23
5	6	10.29	33	0	287.01
6	6	10.6	33	0	295.65
7	6	10.9	29	0	187.15
8	6	10.9	31	4	309.23
9	6	12.11	30	0	227

Table 7. Experiments Results When Soil Is in Loose OMC Condition [Abdoullah Namdar, 2009]

Model No	OMC (%)	γ (KN/m^3)	Φ Degree	C (KN/m^2)	S. B. C (KN/m^2)
1	11.2	10.8	27	10	279.61
2	10.61	10.29	33.5	0	302.58
3	10.72	14.4	23	34	454.31
4	12.15	13.61	32	4	416.26
5	22.39	11.35	24	6	171.96
6	18.86	11.62	31	4	324.93
7	14.56	14.41	20	10	157.56
8	14.23	11.08	28.5	10	326.59
9	14.56	11.2	26	2	336.07

Table 8. Experiments Results When Soil Is in Compacted OMC Condition [Abdoullah Namdar, 2009]

Model No	OMC (%)	γ (KN/m^3)	Φ Degree	C (KN/m^2)	S. B. C (KN/m^2)
1	11.2	21.94	38	21	2036.22
2	10.61	21.83	39	12	1926.51
3	10.72	23.46	39	46	3334.44
4	12.15	23.82	36	28	1833.97
5	22.39	20.09	32	20	888.70
6	18.86	20.95	32	26	1026.83
7	14.56	23.35	18	44	427.74
8	14.23	20.96	30	28	718.00
9	14.56	21.61	28	26	700.05

The soil mixing process will be affected by several factors simultaneously [S. LARSSON et al, 2005]. The proper selection and evaluation of a soil improvement technique for use at a particular site is neither a simple nor a single out come proposition [Salah Sadek and Gabriel Khoury, 2000]. Ground improvement by soil mixing method is highly variable, and this has a nonlinear impact on reliability analyses for soil foundation supported structures [George M. Filz, 2007]. Deep soil mixing method is an extremely valuable competitive and useful ground engineering technology if applied correctly, designed properly, and constructed efficiently [Donald A. Bruce, 2000]. These works draw attention to the importance of designing soil foundation and soil improvement, it is effective with structure stability.

There is reported that the mineralogical could significant effect on the thermal conductivity and the swelling capacity; on the contrary, it was negligible on the water retention property, the investigation finally analyzed to make clear the effects of mineralogical composition on the hydraulic, mechanical and thermal properties. [A. M. Tang et al, 2010].There also several investigation on different clay mineral for retention capacity and their swelling potential and also thermal connectivity, they observed that this parameter depended not only on the water content, the dry density, and the microstructure of soil samples, but also on the mineralogical composition of the clay and also it is reported that the thermal conductivity of compacted bentonite depended mainly on the composition of quartz, which has a thermal conductivity much higher than that of other minerals [Marcial D et al, 2002 & Madsen F T, 1998, & Coulon H, et al., 1987&Tang A M, et al, 2008]

The table 4-8 and fig 2 indicated that due to increasing mixed soil moisture the mechanical properties leads to be weak. The mixed soil type five consist of 55% red soil and 45% black soil in the loose condition shown safe bearing capacity very similar to mixed soil type 2 and 3, the mixed soil type

2 consist of 55% red soil and 45% gravel 2mm and the mixed soil type 3 consist of 55% red soil and 45% gravel 4mm respectively, it could be concluded that in a loose condition it is economic to use mixed soil type 5. In the mixed soil type 5 due to availability of Pyrophyllite mineral in the black soil, the compaction technique could not increased soil mechanical properties, it could be mention that presence of Pyrophyllite mineral in any natural soil, there is not possibility of soil improvement by compaction technique, it is resulted reverse.

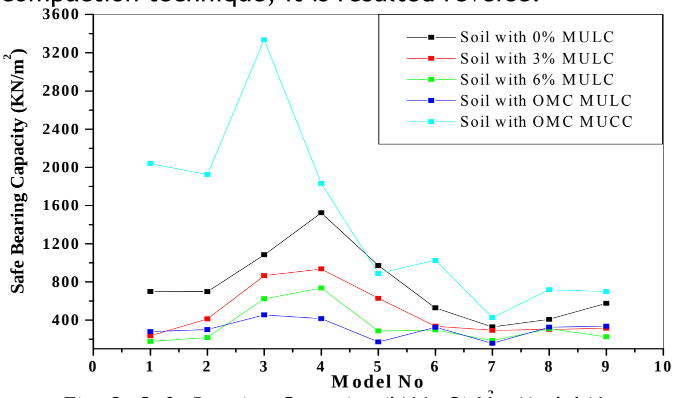

Fig. 2. Safe Bearing Capacity (kN/m2) Vs. Model No

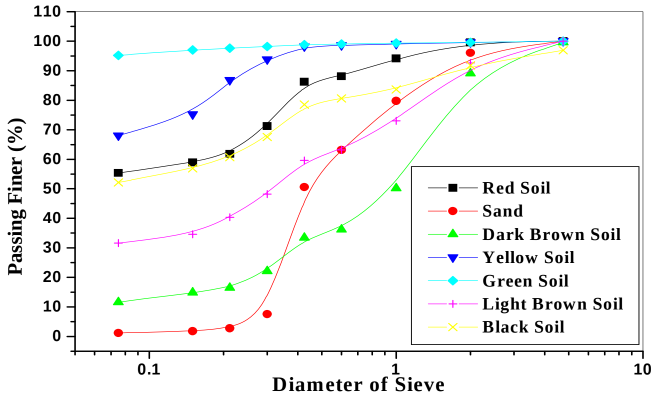

Fig. 3. Results of sieve analysis of soils [Abdullah Namdar, 2009]

The fig 3 indicated that, the red soil and black soil have very similar distribution size particles and it could mention mixed soil types 5 and 1 have very close morphology, but the mixed soil type 1 when is under compaction exhibited maximum level of density and from other hand for mixed soil type 5 could not apply compaction technique, and it is resulted reverse, this is another strong evidence of mineralogy play important factor for improving soil foundation. It has been mentioned in this research paper due to presence of Pyrophyllite mineral, it is observed the negative correlation between soil compaction techniques with enhancement of soil foundation bearing capacity, and from table 3 and soil mineralogy investigation could observe that gathering Illite, Muscovite, and Sauconite in a soil lead to achieving maximum level of density.

CONCLUSION

- The soil mineralogy have been used for assessing soil foundation bearing capacity, and there is direct correlation between soil mineralogy and soil foundations stability
- The angle of friction, cohesion and unit weight of mixed soil is changed based on variation of soil mineralogy and moisture
- Due to presence of Pyrophyllite mineral, it is observed that the negative correlation between soil compaction technique with enhancement of soil foundation bearing capacity
- It observe that gathering Illite, Muscovite, and Sauconite in a soil lead to achieve maximum level of density
- It was find that the changing soil mineralogy lead to modify soil foundations behavior, and It could landslide mitigate from understanding soil mineralogy without using other technique, or predict landslide phenomena based on identifying soil mineralogy

NOMENCLATURE

Φ [∘]= Friction Angle
C [kN/m^2] = Soil Cohesion
OMC % = Optimum Moisture Content %
SBC [kN/m^2] = Safe Bearing Capacity
γ [kN/m^3] = Unit Weight
F = Safety Factor = 3
MULC = Moisture under Loose Condition
MUCC = Moisture under Compacted Condition

REFERENCES

[1.] M. Tang, Y. J. Cui (2010), Journal of Rock Mechanics and Geotechnical Engineering, 2 (1): 91–96
[2.] Abdoullah Namdar (2009), Identification of Mixed Soil Characteristics by Application of Laboratory Test, EJGE, Vol. 14, Bund. B, USA
[3.] Abdoullah Namdar et al (2009), Bearing and liquefaction evaluation of mixed soils, Ingenierías, Vol. XII, No. 44, Mexico
[4.] Abdoullah Namdar et al (2009), Bearing Capacity of Mixed Soil Model, Frattura ed Integrità Strutturale, 7, 73-79; DOI: 10.3221/IGF-ESIS.07.06, Italy
[5.] Bahner, Eric W., Naguib, Aiman M. (2000). "Ground Improvement for Large above Ground Petroleum Storage Tanks Using Deep Mixing", GEODENVER 2000, Denver, CO, in press.

[6.] Bergado D.T. et al., (1990), "Settlement of Bangna-Bangpakong Highway on Soft Bangkok clay", Journal of Geotechnical Engineering, ASCE, Vol. 116, No. 1, 136-155.
[7.] Budhu, M. and Al-Karni, A (1993), "Seismic bearing capacity of soils" Geotechnique, 43(1), 181-187
[8.] Coulon H, Lajudie A, Debrabant P, et al. Choice of French clays as engineered barrier components for waste disposal. Materials Research Society Symposium Proceedings, 1987, 84: 813-824.
[9.] Donald A. Bruce (2000), An introduction to the Deep Soil Mixing Methods as Used in Geo-technical applications, US department transportation, federal highway administration, Office of infrastructure Research and Development 3300 Georgetown Pike McLean, VA 22101-2296.
[10.] Dormieux, L. and Pecker, A. (1995), "Seismic bearing capacity of foundation on cohesionless soil" Journal of Geotechnical Engineering Division, ASCE, 121(3), 300-30
[11.] George M. Filz (2007), "Load Transfer, Settlement, and Stability of Embankments Founded on Columns Installed by Deep Mixing Methods", National Technical University of Athens School of Civil Engineering Geotechnical Department – Foundation Engineering Laboratory
[12.] http://serc.carleton.edu/research_education/geochemsheets/techniques/XRD.html
[13.] J Hadjigeorgiou et al (2006), A road embankment failure near pentalia in Southwest Cyprus, International Symposium on Stability of Rock Slopes in Open Pit Mining and Civil Engineering, The South African Institute of Mining and Metallurgy
[14.] James R. Connolly, for EPS400-002, Introduction to X-Ray Powder Diffraction, Spring 2007
[15.] Kenneth B. Andromalos, Yasser A. Hegazyand Brian H. Jasperse (2000), Stabilization Of Soft Soils By Soil Mixing, Andromalos, Hegazy and Jasperse
[16.] Kumar, J. and Kumar, N. (2003), "Seismic Bearing Capacity of Rough Footings on Slopes using Limit Equilibrium" Geotechnique, Institution of Civil Engineers, UK, 53(3), 363-369
[17.] Kumar, J. and Rao, V.B.K.M. (2002), Seismic Bearing Capacity Factors for Spread Foundations. Geotechnique, Institution of Civil Engineers, UK, 52(2), 2002, 79-88
[18.] Kumar, J. and Rao, V.B.K.M. (2003), Seismic Bearing Capacity of Foundations on Slopes, Geotechnique, Institution of Civil Engineers, UK, 53(3): 347-361
[19.] Liew Shaw-Shong (2005), Soil Nailing for Slope Strengthening, Geotechnical Engineering, Gue & Partners Sdn Bhd, Kuala Lumpur, Malaysia
[20.] Lin K.Q. and Wong I.H. (1999), "Use of deep cement mixing to reduce settlements at bridge approaches", Journal of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 125, No. 4, 309-320.
[21.] Liver Norman L et al (1954). "Development and Applications of Intrusion Grout Mixed-in-Place Piles", Civil Engineering, March 1954, 56-57
[22.] Madsen F T. Clay mineralogical investigations related to nuclear waste disposal. Clay Minerals, 1998, 33 (1): 109–129.
[23.] Marcial D, Delage P, Cui Y J. On the high stress compression of bentonites, Canadian Geotechnical Journal, 2002, 39 (4): 812–820.
[24.] Nicholson P.J., Mitchell J.K., Bahner E.W. and Moriwaki, Y (1998), "Design of composite gravity wall constructed by soil mixing", Soil Improvement for Big Digs, Geotechnical Special Publication, ASCE, No. 81, Boston, MA, October, 27-40.
[25.] Richards, R., Elms, D. G., and Budhu, M. (1993), "Seismic bearing capacity and settlement of foundations" Journal of Geotechnical Engineering Division, ASCE, 119(4), 662-674
[26.] Ryan Christopher R., Jasperse Brian H. (1989). "Deep Soil Mixing at the Jackson Lake Dam", ASCE Geotechnical and Construction Divisions Special Conference, Evanston, IL, June 25-29, 2
[27.] S. LARSSON, M. DAHLSTROM and B. NILSSON (2005), "Uniformity of lime-cement columns for deep mixing: a field study", Ground Improvement, No. 1, PP 1–15.
[28.] Salah Sadek and Gabriel Khoury (2000), Soil and Site improvement guide: and educational tool for Engg ground modification, Int. J. Engng Ed, Vol. 16, No.6, PP, 499-508, Britain
[29.] Sarma, S.K. and Iossifelis, I.S. (1990), "Seismic bearing capacity factors of shallow strip footings." Geotechnique, 40(2), 265-273.
[30.] Sasan Mafian (2009), Live Poles for Slope Stabilization in the Tropical Environment, EJGE, Vol. 14, Bund. G
[31.] Soubra, A. H. (1997). "Seismic bearing capacity of shallow strip footings in seismic conditions" Proc. of Institution of Civil Engineers, Geotechnical Engineering, 125, 230-241
[32.] Soubra, A. H. (1999). "Upper-bound solutions for bearing capacity of foundations" Journal of Geotechnical and Geoenvironmental Enginnering, ASCE, 125(1), 59-68
[33.] Tang A. M, Cui Y J, Le T T. A study on the thermal conductivity of compacted bentonites, Applied Clay Science, 2008, 41(3–4): 181–189.
[34.] Zhu, D. (2000). "The least upper-bound solutions for bearing capacity factor N" Soils and foundations, Vol. 40(1), 123-129.

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