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# ENHANCEMENT SLOPE DESIGN USING MINERALOGY TREATMENT

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**ABSTRACT:** *The application of mixed soil by natural local material in slope construction is a novel technique. It is possibility of development new materials to satisfy slope safety requirements, in this regard mineralogy of different natural soils have been considered, and affect of mixed soil matrices in the identified slope behavior analyzed. The result of investigation revealed this method is fast, economic, trustable and easiest way of slope construction and it is due to understanding of soil mineralogy in geotechnical engineering, and the factor of safety has direct correlation with soil angle of friction and cohesive as well as unit weight.*
**KEYWORDS:** *Local Material, Numerical Analysis, New Material*

## INTRODUCTION

*To increase safety of any structure and improve of soil foundation, experiments in laboratory and in situ applications along with computer modeling could lead to find economical constructed slope, and also it is standard method of starting construction activities for better understanding of material characteristics in the body of earth structure.*

*It has been reported on a generic earth fill dam model and investigates, probabilistically, downstream and upstream slope stability, as significant limit states governing the long-term performance. Specific variables that define failure modes are identified and their probabilistic models defined [1]. 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, geological structure and the presence of weak rocks and cohesive soils [2]. It is presented slope and embankment analysis by some methods including Finite Element (FE) and Limit Equilibrium (LE) were used for evaluation failed slopes at Talaimai location of the Rajshahi City [3]. There is a scientific research on determine the mechanism of internal soil erosion resistance to soil slope instability. A laboratory study has been carried out to characterize the soil internal erosion resistance to slope instability due to rainwater infiltration and the effect of percentage of course to fine-grained soils composition [4]. It has been studied of the development in geotechnical engineering and the advancement in the earth moving machineries enabled the construction of high earth and rock-fill dams. The flexibility of the materials provides excellent seismic stability to the structure. It could be evaluating the stability analysis of zoned dam with different materials and hydraulic properties of the construction materials [5]. 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. Among all categories of landslides, shallow slope failures which affect many hill slopes and earthwork projects and pose the most costly maintenance problem, to overcome to these problems Live Pole technique for soil improvement in shallow slope failures has been suggested [6]. The experiments are conducted in the Geo-technical Engineering Laboratory of S. J. College of Engineering, Mysore. In the present experiments, several models have been developed to improve red soil mechanical characteristics. It is to study slope construction from local and economical materials in the Mysore city of India, the six types of soils along with the two types of gravel and sand have been selected to evaluation of characteristics of 31 mixed soils under loose dry condition and out of these 5 models as per their characteristics have been selected for future investigation.*

## METHODOLOGY AND EXPERIMENTS

*It is quite clear a mixed soil characteristic is totally different from individual soil. Earth slopes are formed for railway formation, highway embankment, earth dam, canal banks and many earth structures. In slope construction from mixed soil for increasing slope stability, employee of different types of soil with proper percentage is best option, in this regard 31 mixed soil types from red plastic soil and black, green, dark brown, yellow and light brown non plastic soils, sand, and two types of gravels 2 mm, 4.75 mm developed, and also from previous investigation (Table 1) safe bearing capacity, angle of friction, unit weight and cohesive of mixed soils sample for computerize model have been used, the Geo-Slope software in identification of models behavior employed and the result of these modeling research work by interpretation of mixed soil types characteristics evaluated. And the XRD results of six soil samples used as starting materials for mixture.*

 

Table 1. Mixed soil models [7]

| Sl. 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 | 15 | 15 | 15 | 0 | 0 | 0 | 0 | 0 |
| 6. | 55 | 0 | 0 | 0 | 45 | 0 | 0 | 0 | 0 |
| 7. | 55 | 0 | 0 | 0 | 0 | 45 | 0 | 0 | 0 |
| 8. | 55 | 0 | 0 | 0 | 0 | 0 | 45 | 0 | 0 |
| 9. | 55 | 0 | 0 | 0 | 0 | 0 | 0 | 45 | 0 |
| 10. | 90 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 |
| 11. | 80 | 0 | 0 | 0 | 4 | 4 | 4 | 4 | 4 |
| 12. | 70 | 0 | 0 | 0 | 6 | 6 | 6 | 6 | 6 |
| 13. | 60 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 8 |
| 14. | 50 | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 |
| 15. | 70 | 0 | 0 | 0 | 10 | 10 | 10 | 0 | 0 |
| 16. | 70 | 0 | 0 | 0 | 10 | 10 | 0 | 10 | 0 |
| 17. | 70 | 0 | 0 | 0 | 10 | 10 | 0 | 0 | 10 |
| 18. | 70 | 0 | 0 | 0 | 10 | 0 | 10 | 10 | 0 |
| 19. | 70 | 0 | 0 | 0 | 10 | 0 | 10 | 0 | 10 |
| 20. | 70 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 10 |
| 21. | 70 | 0 | 0 | 0 | 15 | 15 | 0 | 0 | 0 |
| 22. | 70 | 0 | 0 | 0 | 15 | 0 | 15 | 0 | 0 |
| 23. | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 15 |
| 24. | 70 | 0 | 0 | 0 | 15 | 0 | 0 | 15 | 0 |
| 25. | 70 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 15 |
| 26. | 70 | 0 | 0 | 0 | 0 | 15 | 15 | 0 | 0 |
| 27. | 70 | 0 | 0 | 0 | 0 | 15 | 0 | 15 | 0 |
| 28. | 70 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 15 |
| 29. | 70 | 0 | 0 | 0 | 0 | 0 | 15 | 15 | 0 |
| 30. | 70 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 15 |
| 31. | 55 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45 |

## RESULTS AND DISCUSSION

*One of the ways in overcoming in the shortage of land in the urban area is improvement of soil properties by grouting, compaction, excavation, replacement of new soil and mitigation of soil by nailing etc, those this method have been adopted by the geotechnical engineering but mixing soil method from local material is new technique could be improve if knowledge of this method properly developed. To feasible evaluation of mixed soil technique in slope construction, four mixed soil types those have better than red plastic soil characteristics to construction of slope has been selected (table 8), it is for application analysis of mixed soil capability in construction industry. At the time of earthquake, soil liquefaction results appeared in the form of ground failure, differential settlements, slides, soil foundation deformation, and reduction of soil bearing capacity. It is a major cause of earth structure collapse [Fig 1].*

*The peaks have been indexed and minerals present in the soils were identified by use of the standard D-spacing and mineral intensity (Table 2-7 and Fig 2.a-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. The mixed soil model mineralogy and morphology are the main factors at play in level of soil bearing capacity, foundation strength and stress sustainability [7].*

*Table 3 indicated of 31 mixed soils characteristics which are soil moisture content, angle of friction, cohesive, unit weight and safe bearing capacity and table 9 mentioned of slope characteristics constructed from mixed soil, these are factors of safety, total resistance moment, total activating moment, total resisting force and total activating force. This novel technique of soil mixing could successfully applied in some areas of urban in improvement of structure foundation and earth structure as well as seismic mitigation. The slope from mixed soil designed to satisfy bearing capacity and economic criteria and achieving of best factor of safety.*

*The results of these computerize modeling [Table 4 and Fig 3-4] revealed soil angle of friction, cohesive and unit weight have positive correlation with total activating force and moment, it is due to mechanical soil characteristics, it appeared in earth structure construction and could be accurate verify by finite element analysis, this is led to understanding of slope stability requirement. One of the methods in slope stability improvement is application of mixed soil technique, it is quite clear by this technique in slope design and analysis easy can achieve to the economic and fast slope construction whit acceptable factor of safety.*

*In the soil composite, angle of friction with the cohesive and unit weight of the soil could be equality important in the slope stability, this is occur due to slope shape, soil nature and slope load sustainability as well as pore water pressure characteristics and all these factors came from soil mineralogy and morphology. There is good agreement revealed between the results of mixed soil and slope construction modeling due to understanding soil mixed behavior, and the results find slope displacement, deformation, collapse, settlement and level of pore water pressure could be controlled if mixed soil technique properly identified and applied. Soil mixed has a significant effect on improvement of slope bearing capacity, if slope is very sensitive in settlement, in this case application of mixed soil method could mitigate slope settlement, and more complex and precise slope behaviors of the soil could be analysis. Therefore, the effects of the factor of safety can be taken into consideration as part of the* *analysis. The effect of soil characteristics and slope geometry on the stability of a slope can also be studied when the all parameters is combined.*

Figure 1. Landslide at Sau Mau Ping in 1976 [8]

Table 2.a XRD data of red soil [7].

| Peak No | 2theta | Flex Width | D-Value | Intensity | $I/I_o$ |
|---|---|---|---|---|---|
| 1 | 19.96 | 0.471 | 4.4447 | 742 | 26 |
| 2 | 20.92 | 0.306 | 4.2428 | 739 | 26 |
| 3 | 22.10 | 0.329 | 4.0189 | 350 | 12 |
| 4 | 26.70 | 0.329 | 3.3360 | 2919 | 100 |
| 5 | 28.04 | 0.329 | 3.1796 | 864 | 30 |
| 6 | 28.76 | 0.353 | 3.1016 | 331 | 12 |
| 7 | 33.26 | 0.353 | 2.6915 | 333 | 12 |
| 8 | 35.02 | 0.400 | 2.5602 | 340 | 12 |
| 9 | 35.82 | 0.424 | 2.5048 | 464 | 16 |
| 10 | 36.60 | 0.306 | 2.4532 | 465 | 16 |
| 11 | 49.66 | 0.376 | 1.8343 | 405 | 14 |
| 12 | 50.22 | 0.353 | 1.8152 | 846 | 29 |

Table 2.b XRD data of black soil [7].

| Peak No | 2theta | Flex Width | D-Value | Intensity | $I/I_o$ |
|---|---|---|---|---|---|
| 1 | 20.800 | 0.282 | 4.2670 | 2297 | 25 |
| 2 | 26.580 | 0.282 | 3.3508 | 9312 | 100 |
| 3 | 27.80 | 0.259 | 3.1974 | 668 | 8 |
| 4 | 29.320 | 0.306 | 3.0436 | 676 | 8 |
| 5 | 36.500 | 0.306 | 2.4597 | 699 | 8 |
| 6 | 39.400 | 0.353 | 2.2851 | 672 | 8 |
| 7 | 40.260 | 0.306 | 2.2382 | 429 | 5 |
| 8 | 42.400 | 0.329 | 2.1301 | 806 | 9 |
| 9 | 50.080 | 0.329 | 1.8199 | 1316 | 15 |

Table 2.c XRD data of yellow soil [7].

| Peak No | 2theta | Flex Width | D-Value | Intensity | $I/I_o$ |
|---|---|---|---|---|---|
| 1 | 9.500 | 0.376 | 9.3020 | 891 | 7 |
| 2 | 12.160 | 0.400 | 7.2725 | 1033 | 8 |
| 3 | 18.740 | 0.376 | 4.7312 | 573 | 5 |
| 4 | 20.900 | 0.400 | 4.2468 | 3549 | 27 |
| 5 | 24.400 | 0.353 | 3.6450 | 887 | 7 |
| 6 | 26.680 | 0.376 | 3.3385 | 13545 | 100 |
| 7 | 28.660 | 0.376 | 3.1122 | 895 | 7 |
| 8 | 32.660 | 0.376 | 2.7396 | 7551 | 56 |
| 9 | 35.880 | 0.400 | 2.5007 | 1336 | 10 |
| 10 | 36.600 | 0.376 | 2.4532 | 1082 | 8 |
| 11 | 39.500 | 0.400 | 2.2795 | 796 | 6 |
| 12 | 43.000 | 0.376 | 2.1017 | 3763 | 28 |
| 13 | 46.840 | 0.400 | 1.9380 | 1131 | 9 |
| 14 | 50.180 | 0.400 | 1.8165 | 1327 | 10 |

Table 2.d XRD data of light brown soil [7].

| Peak No | 2theta | Flex Width | D-Value | Intensity | $I/I_o$ |
|---|---|---|---|---|---|
| 1 | 19.880 | 0.447 | 4.4624 | 567 | 10 |
| 2 | 20.880 | 0.282 | 4.2509 | 1201 | 21 |
| 3 | 22.080 | 0.259 | 4.0225 | 646 | 11 |
| 4 | 26.680 | 0.282 | 3.3385 | 5937 | 100 |
| 5 | 27.420 | 0.282 | 3.2500 | 801 | 14 |
| 6 | 27.980 | 0.306 | 3.1862 | 2708 | 46 |
| 7 | 36.600 | 0.282 | 2.4532 | 658 | 12 |
| 8 | 41.780 | 0.353 | 2.1602 | 512 | 9 |
| 9 | 50.160 | 0.306 | 1.8172 | 697 | 12 |

Table 2.e XRD data of dark brown soil [7].

| Peak No | 2theta | Flex Width | D-Value | Intensity | $I/I_o$ |
|---|---|---|---|---|---|
| 1 | 9.460 | 0.424 | 9.3412 | 746 | 29 |
| 2 | 10.520 | 0.376 | 8.4023 | 1147 | 44 |
| 3 | 18.440 | 0.400 | 4.8075 | 735 | 28 |
| 4 | 24.660 | 0.400 | 3.6072 | 1770 | 67 |
| 5 | 25.300 | 0.353 | 3.5173 | 525 | 20 |
| 6 | 26.400 | 0.424 | 3.3732 | 663 | 26 |
| 7 | 27.220 | 0.376 | 3.2734 | 617 | 24 |
| 8 | 28.520 | 0.376 | 3.1271 | 1882 | 72 |
| 9 | 30.960 | 0.424 | 2.8860 | 2646 | 100 |
| 10 | 35.260 | 0.400 | 2.5433 | 1090 | 42 |

Table 2.f XRD data of dark green soil [7].

| Peak No | 2theta | Flex Width | D-Value | Intensity | $I/I_o$ |
|---|---|---|---|---|---|
| 1 | 20.880 | 0.306 | 4.2509 | 433 | 15 |
| 2 | 21.960 | 0.329 | 4.0442 | 1138 | 40 |
| 3 | 23.680 | 0.447 | 3.7542 | 683 | 24 |
| 4 | 24.380 | 0.353 | 3.6480 | 567 | 20 |
| 5 | 26.620 | 0.353 | 3.3459 | 2573 | 89 |
| 6 | 27.880 | 0.565 | 3.1974 | 2910 | 100 |
| 7 | 29.780 | 0.447 | 2.9976 | 1214 | 42 |
| 8 | 30.360 | 0.353 | 2.9417 | 1027 | 36 |
| 9 | 30.900 | 0.329 | 2.8915 | 489 | 30 |
| 10 | 35.440 | 0.353 | 2.5308 | 1301 | 45 |
| 11 | 42.220 | 0.612 | 2.1387 | 529 | 19 |
| 12 | 51.480 | 0.329 | 1.7737 | 419 | 15 |

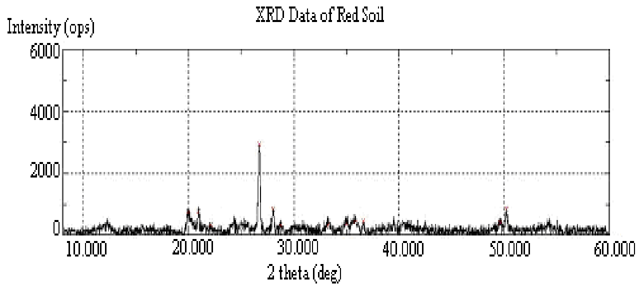


Fig.2.a. XRD Data of Red Soil [7]

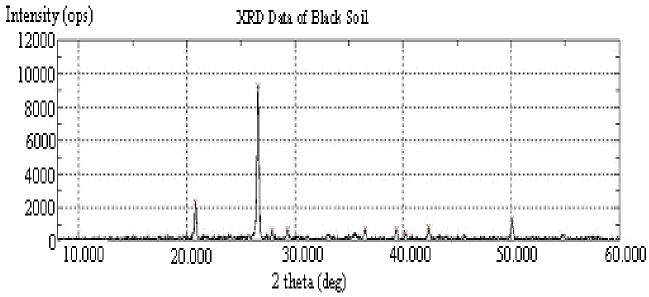


Fig.2.b. XRD Data of Black Soil [7]

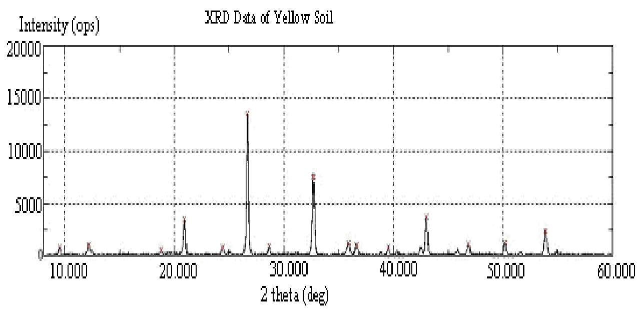


Fig.2.c. XRD Data of Yellow Soil [7]

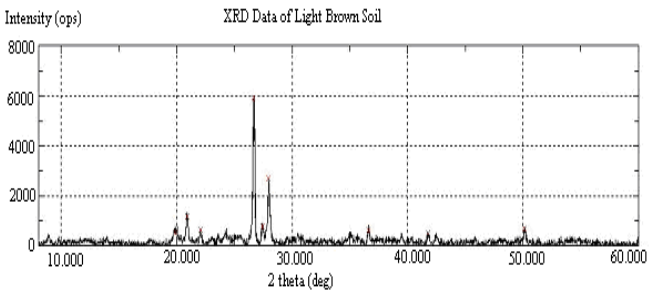


Fig.2.d. XRD Data of Light Brown Soil [7]

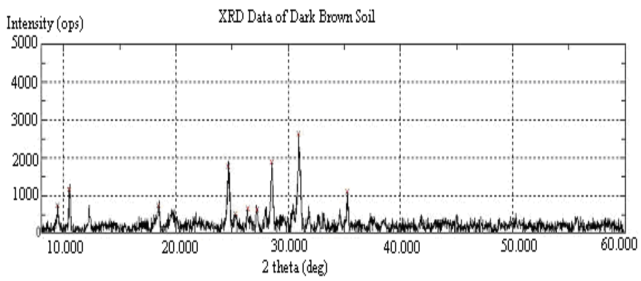


Fig.2.e. XRD Data of Dark Brown Soil [7]

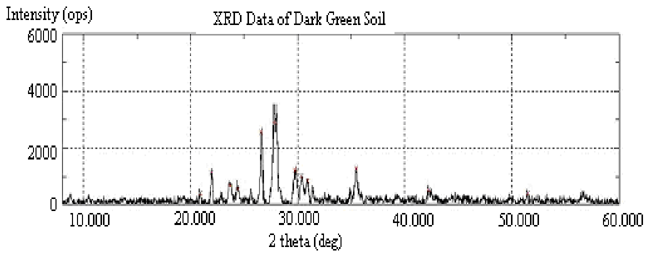


Fig.2.f. XRD Data of Dark Green Soil [7]

Table 3 Experiments Results When Soil Is in Loose 0% Moisture Condition [9]

| Sl. No | Model No | Zero % Moisture Content | $\gamma$ (KN/m³) | Φ Degree | C (KN/m²) |
|---|---|---|---|---|---|
| 1 | 1 | 0 | 11.808 | 38 | 0 |
| 2 | 2 | 0 | 12.54 | 35 | 10 |
| 3 | 3 | 0 | 13.93 | 36.5 | 14 |
| 4 | 4 | 0 | 12.71 | 42 | 0 |
| 5 | 5 | 0 | 13.32 | 42 | 0 |
| 6 | 6 | 0 | 11.5 | 37 | 12 |
| 7 | 7 | 0 | 12.11 | 36 | 0 |
| 8 | 8 | 0 | 13.26 | 32 | 0 |
| 9 | 9 | 0 | 11.38 | 35 | 0 |
| 10 | 10 | 0 | 10.29 | 37 | 4 |
| 11 | 11 | 0 | 10.9 | 36 | 0 |
| 12 | 12 | 0 | 12.35 | 33 | 0 |
| 13 | 13 | 0 | 11.5 | 35 | 0 |
| 14 | 14 | 0 | 12.72 | 36 | 0 |
| 15 | 15 | 0 | 11.5 | 35 | 0 |
| 16 | 16 | 0 | 11.93 | 33 | 0 |
| 17 | 17 | 0 | 12 | 35 | 0 |
| 18 | 18 | 0 | 12.11 | 37 | 0 |
| 19 | 19 | 0 | 11.02 | 35 | 0 |
| 20 | 20 | 0 | 11.51 | 31 | 12 |
| 21 | 21 | 0 | 12.42 | 35 | 0 |
| 22 | 22 | 0 | 11.81 | 35 | 8 |
| 23 | 23 | 0 | 13.32 | 34.5 | 0 |
| 24 | 24 | 0 | 11.51 | 33 | 0 |
| 25 | 25 | 0 | 12.72 | 34 | 0 |
| 26 | 26 | 0 | 14.05 | 34 | 0 |
| 27 | 27 | 0 | 12.11 | 32.5 | 0 |
| 28 | 28 | 0 | 12.72 | 37 | 0 |
| 29 | 29 | 0 | 12.72 | 34 | 6 |
| 30 | 30 | 0 | 13.02 | 35.5 | 0 |
| 31 | 31 | 0 | 11.2 | 37 | 0 |

Table 4. Analytical Result of Slopes in Morgenstern- Price Method

| Model No | Factor of Safety | Total volume (M³) | Total Mass (Kg) | Total Resistance Moment (KN. M) | Total Activating Moment(KN. M) | Total Resisting Force (KN) | Total Activating Force (KN) |
|---|---|---|---|---|---|---|---|
| 3 | 1.939 | 234.44 | 3265.7 | 45887 | 23664 | 1933 | 999.37 |
| 6 | 1.844 | 275.44 | 3171.3 | 42075 | 22821 | 1689.3 | 916.44 |
| 5 | 1.71 | 154.64 | 2059.8 | 28084 | 16426 | 1241.6 | 728.59 |
| 4 | 1.689 | 154.64 | 1965.4 | 26471 | 15674 | 1169.2 | 694.81 |
| 1 | 1.435 | 154.64 | 1826 | 20899 | 14562 | 922 | 644.85 |

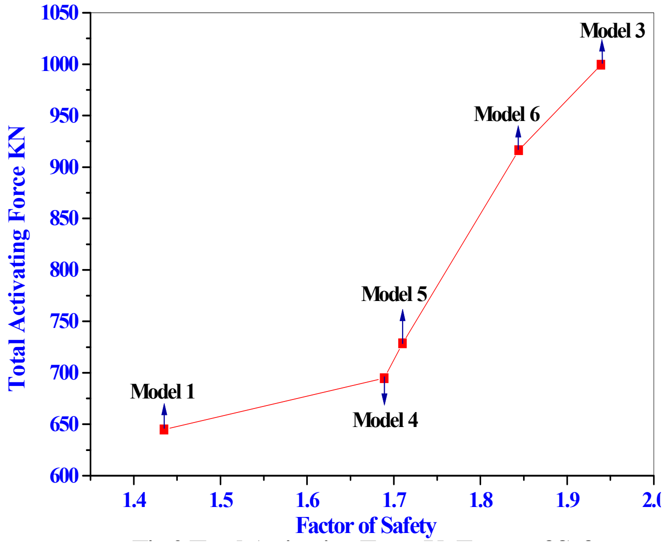


Figure 3. Total activating force vs. Factor of safety

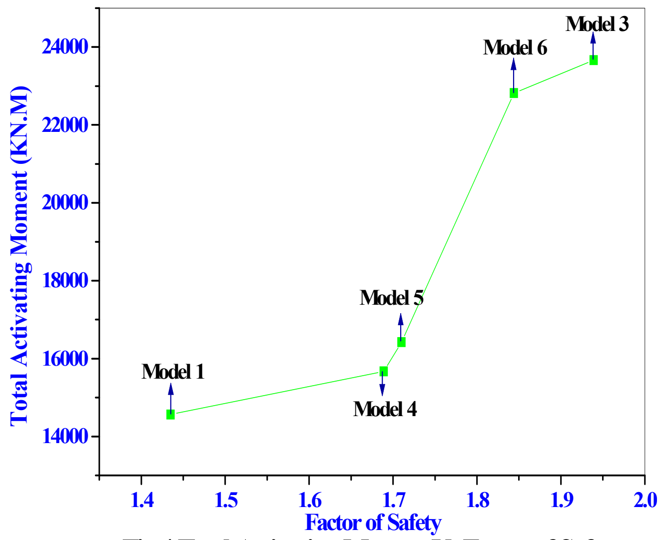


Figure 4. Total activating moment vs. Factor of safety

## CONCLUSIONS

- The structure modeling is a step of any construction activities and it is fast, economic, trustable and easiest way of slope stability evaluation, and it is achieved if soil mixture mineralogy identified
- Soil angle of friction, cohesive and unit weight have positive correlation with slope factor of safety

- To achieving acceptable factor of safety, it is needed present of high level of soil angle of friction and cohesive as well as unit weight
- If the soil angle of friction, cohesive and unit weight increased simultaneously it will have best influence in controlling slope factor of safety, if any of these three be weak could not be observed acceptable of factor of safety, it could be suggested if a mixed soil is weak in cohesion to improved of that should amended with pure clay mineral, and to increase of angle of friction could use of angular soil in development of mixed soil and to modification of unite weight could use of soil consist of heavy mineral

## NOMENCLATURE

| | |
|---|---|
| Φ [°] | = Friction Angle |
| C [kN/m2] | = Soil Cohesivity |
| OMC % | = Optimum Moisture Content % |
| SBC [kN/m2] | = Safe Bearing Capacity |
| γ [kN/m3] | = Unit Weight |
| F | = Safety Factor = 3 |

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