Analysis of Slope Stability on Earth Structures by Modeling

Abdoullah Namdar & Azam Khodashenas Pelko

Mysore University, Mysore, India
email: **ab_namdar@yahoo.com**

Abstract – The numerical simulation could be used in approaching soil structure behavior. The application of soil mixed matrices for construction earthen structure is novel technique and shown mixture soil function. This paper deals with numerical simulation technique for construction of earthen soil. The result revealed this investigation could lead to have stable soil structure using nearest local material, reducing project cost, solve of geotechnical problem and accurate understanding of soil property when it is developed under different types of geometry and water level.

Keyword: Modeling, Mixed Soil, Liquefaction and Soil Foundation Geometry

1. Introduction

Several methods could be applied for increasing slope stability, using computer modeling is an advance and accurate technique for understanding slope behavior.

There are several researches on assessing soil slops factor of safety, stability, critical failure surface and corresponding factor of safety [1-5]. It has been studied influence of root trees on slope stability and different factors like slope geometry and gradient, geologic materials, stratigraphy and hydrology [6]. The stability analysis of soft ground is a topic of interest in many engineering problems such as material stack ground, oilcan ground, embankment ground of freeway and large area filling ground of artificial hills which are constructed in stages [7]. Many researchers had provided the theory about shear strength increment, they provided some calculation equations based on remolded soft soil and discussed their validity, without considering the structure property of soft soil [8]. There is investigation on the soft soil and cement action of particles, and the calculation modeling was considering base on structure property of soft soil [9-16]. The characteristics of 31 mixed soils under loose optimum moisture content (OMC) condition in the laboratory have been determined and using computer modeling, XRD result, the characteristics of slopes base on geometry, availability of water and mineralogy of soil have been evaluated.

2. Methodology and Experiments

The computerized modeling is a novel method for solving Geotechnical problems. It is quite clear a mixed soil characteristic is totally different from individual soil. In slope construction from mixed soil for increasing slope stability, different types of soil with proper percentage is best option, the XRD results of six soil samples used for creating mixed soil types, 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 1-3) mixed soil percentage, mineralogy, angle of friction, unit weight and cohesive of mixed soils sample for slope computerize modeling have been used, the Geo-Slope software for identification of models behavior employed and the results of these modeling for development of best slope model evaluated. Table 2 is indicated soil mineralogy used for mixed soil technique. The factor of safety is equal to [Total resistance moment/ Total activating moment] or [Total resistance force/ Total activating force]

Table 1 Mixed soil models [17]

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

Table 2 Mineral of Soil Sample [18]

Sl. No	Soil Name	Minerals in the soil sample
1	Red soil	quartz, illite, muscovite, saponite, sauconite and carbonate- fluorapatite
2	Black soil	quartz, pyrophyllite, carbonate- fluorapatite and orthochamosite
3	Yellow soil	quartz, brucite, clinochlore and sandoite
4	Light brown soil	quartz and carbonate
5	Dark brown soil	nacrite, odinite, amesite, chamosite and biotite
6	Green soil	quartz, cancrisilite, chamosite, orthochamosite and brucite

3. Results and Discussion

It is well know the compaction method is an easy function for increasing soil mechanical properties but due to some limitation during the construction it is too important of investigates on loose soil and increase of their mechanical properties from local soil, without applying compaction technique. For stabilization of earth structure, the mixed soil method could be one of the novel techniques if compacting of area be impossible.

The figures 1-4 shown the type of slope possibility collapse, the model type 1 with small dimension under saturated condition has maximum affected and also in model type 2 due to increasing geometry dimension slope possibility collapse is decreased, the slope possibility damage during lack of water significantly is decreased.

The tables 4-5 and figures 5-6 indicating slope model factor of safety and pore water pressure, in the table 4 could be observed in some model due to increasing slope dimension, model could have factor of safety and it is designable.

The figure 5-6 shown the difference between model type 1and 2 when they are saturated and under optimum moisture content.

The self weight of earth structure increased due to increasing its dimension, it has direct correlation with cohesion, pore water force, base shear force and base normal force. The self weight is act like static force for achieving compaction and it could lead to rising soil cohesion, pore water force. The pore water force resulted of liquefaction and the cohesion of soil decreased of liquefaction, therefore liquefaction is depending of these two factors.

The sand is very vulnerable against liquefaction the phenomenon is more catastrophic if sand be under loose condition. If the soil mechanical properties be similar to the sand, to improvement of the soil characteristics clay minerals presented in some other soil could change of soil characteristics. The analysis of slope has close similarity with structure analysis, it is observed all load sustainability, deformation, settlement and reliability and safety of soil structure are not only depend on strength of material, but soil structure geometry has also play one of the important factor in the design and analysis of slope.

Using standard D-spacing and mineral intensity (Table 2), 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 slope stress sustainability [18]. Proper selection of mixtures made of suitable material could significantly improve soil bearing capacity. It is possible for liquefaction mitigation to employ the soil mixing method. In design of soil mixing for liquefaction mitigation, finer material mixtures in model have positive correlation with soil bearing capacity. Soil mixing technique could seriously improve the ability of soil resistance if it is faces shear failure [17]. The geometry of slope could be an important factor in controlling of slope mechanical characteristics. It is find the direct correlation between soil mineralogy and slope geometry in controlling soil mechanical properties, the factor of safety at any earthen structure could be modified by understanding of accurate soil mineralogy.

Table 3 Experiments Results of Mixed Soil under Loose OMC Condition [18]

Sl. No	Model No	Optimum Moisture Content (%)	γ (kN/m^3)	Φ Degree	C (kN/m^2)
1	1	11.2	10.8	27	10
2	2	10.61	10.29	33.5	0
3	3	10.72	14.4	23	14
4	4	12.15	13.61	32	4
5	5	9.58	13.32	27	16
6	6	22.39	11.35	24	6
7	7	18.86	11.62	31	4
8	8	14.56	14.41	20	10
9	9	14.23	11.08	28.5	10
10	10	16.83	10.11	32	10
11	11	18.27	10.6	25	8
12	12	16.76	11.8	20	24
13	13	20.21	12.23	17	14.5
14	14	18.68	11.2	21	14
15	15	19.34	11.5	21	10
16	16	16.55	9.99	23.5	20
17	17	21.14	11.27	18	19
18	18	20.79	12.89	13	20
19	19	16.31	10.05	26.5	8
20	20	20.88	10.29	25	18
21	21	23.00	10.9	22	20.5
22	22	20.06	10.23	21	15
23	23	20.11	11.08	12	22
24	24	20.75	9.69	28.5	7
25	25	22.69	9.99	18	11
26	26	18.87	10.78	22.5	8
27	27	20.31	9.99	19.5	2
28	28	19.51	10.9	21	14
29	29	20.52	10.72	15	16
30	30	18.99	10.9	18	14
31	31	14.56	11.2	26	2

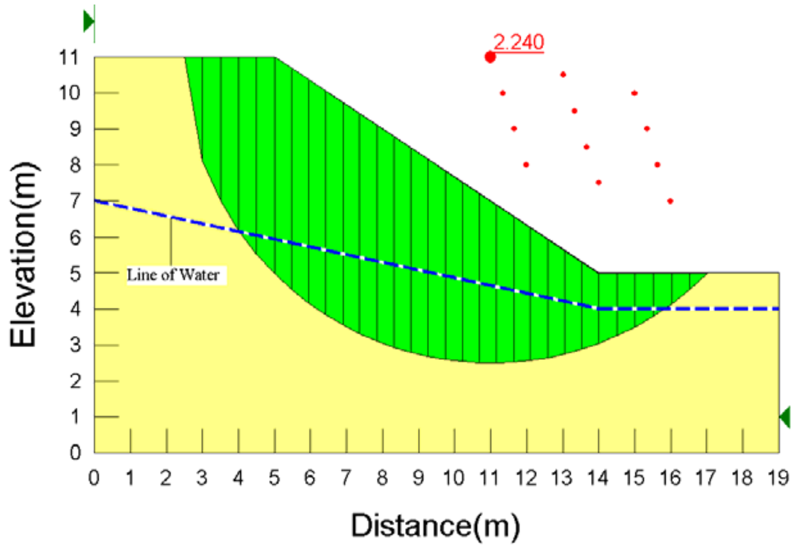

Fig.1 slope type 1 with soil type 1 under saturated condition

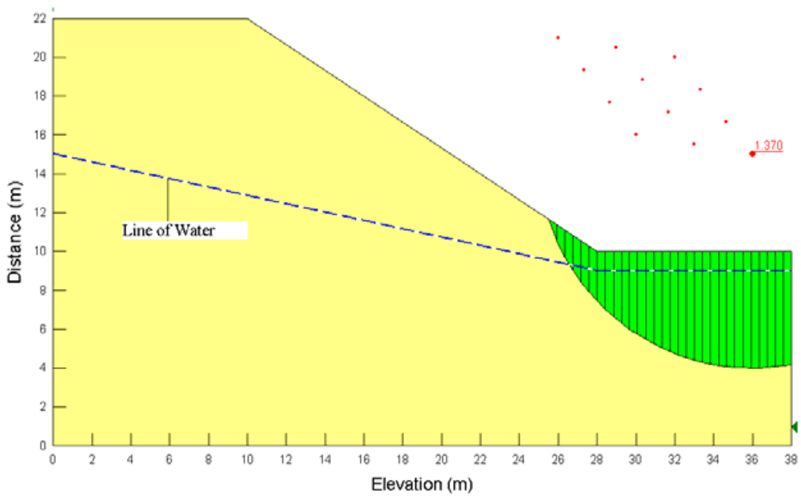

Fig.2 slope type 2 with soil type 1 under saturated condition

Table 4 Slopes analytical results under loose saturated condition by Morgenstern–price method

Sl No	Model No	Cohesion strength (kN/m^2)	Model Types 1			Model Types 2		
			Factor of safety	Cohesion force (kN/m^2)	Maximum of Pore water pressure (kN/m^2)	Factor of safety	Cohesion force (kN/m^2)	Maximum of Pore water pressure (kN/m^2)
1	1	10	2.24	4.8701	22.887	1. 37	4.1668	49.032
2	2	0	1.453	0	19.615	0.5766	0	49.032
3	3	14	-	-	-	1.62	10	49.038
4	4	4	1.956	1.8434	17.893	1.241	1.6667	49.032
5	5	16	2.635	7.7921	22.887	1.913	7.2729	49.037
6	6	6	1.682	2.922	22.887	0.9826	2.5001	49.032
7	7	4	1.884	1.8434	17.893	1.015	1.6667	49.032
8	8	10	1.72	4.6085	17.893	1.28	7.1429	49.038

9	9	10	2. 311	4.8701	22.887	1.416	4.1668	49.032
10	10	10	2.546	4.8701	22.887	1. 405	4.1668	49.032
11	11	8	1.942	3.896	22.887	1.134	3.3335	49.032
12	12	24	-	-	-	2.147	21.054	50.584
13	13	14.5	2.057	7.0616	22.887	1.45	12.72	50.584
14	14	14	2.294	6.8181	22.887	1.575	10	49.038
15	15	10	1.896	4.8701	22.887	1.276	4.1668	49.032
16	16	20	6.082	7.1436	9.8	2.105	17.545	50.584
17	17	19	-	-	-	1.794	16.667	50.584
18	18	20	-	-	-	1.659	14.286	49.038
19	19	8	2.035	3.896	22.887	1.118	3. 3335	49.032
20	20	18	2.993	8.7661	22.887	2.004	15.79	50.584
21	21	20.5	5.737	7.3222	9.8	2.049	17.983	50.584
22	22	15	2.49	7.3051	22.887	1.664	13.159	50.584
23	23	22	-	-	-	1.917	15.714	49.038
24	24	7	2.04	3.409	22.887	1.008	2.9168	49.032
25	25	11	1.948	5.3571	22.887	1.281	7.8571	49.032
26	26	8	1.809	3.896	22.887	1.101	3.3335	49.032
27	27	2	1.046	0.769	19.615	0.4358	0.8334	49.032
28	28	14	2.32	6.8181	22.887	1.579	10	49.038
29	29	16	-	-	-	1.525	14.036	50.584
30	30	14	2.176	6.8181	22.887	1.484	12.281	50.584
31	31	2	1.396	0.769	19.615	0.6853	0.83337	49.032

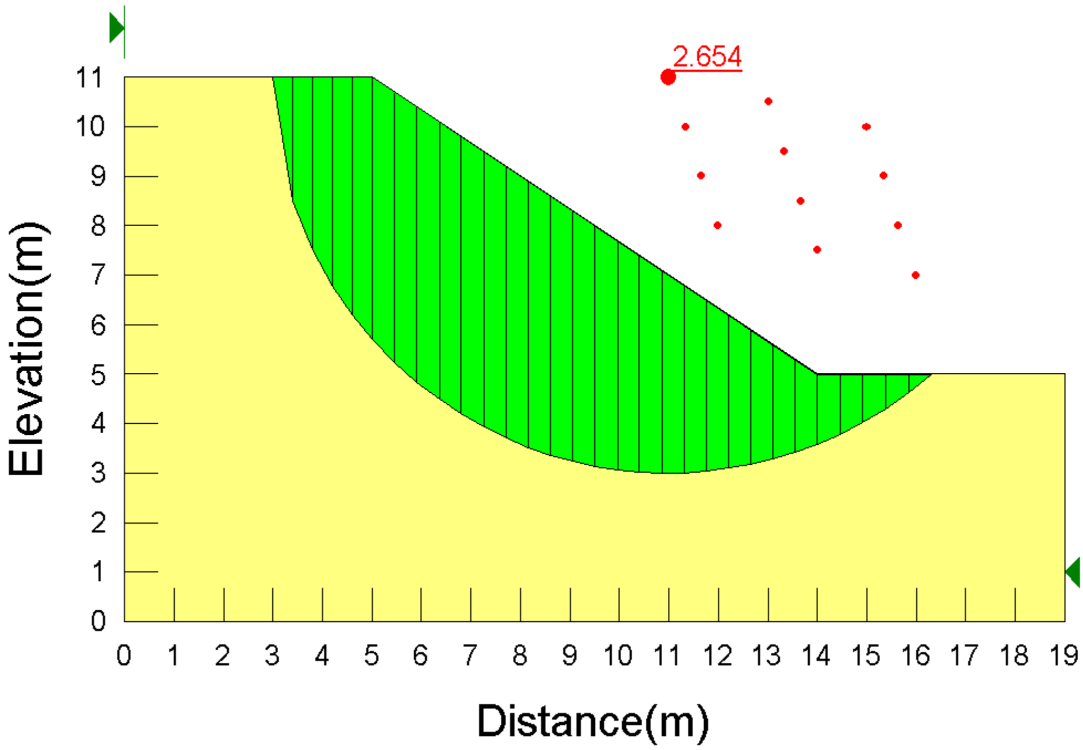

Fig.3 slope type 1 with soil type 1 under OMC condition

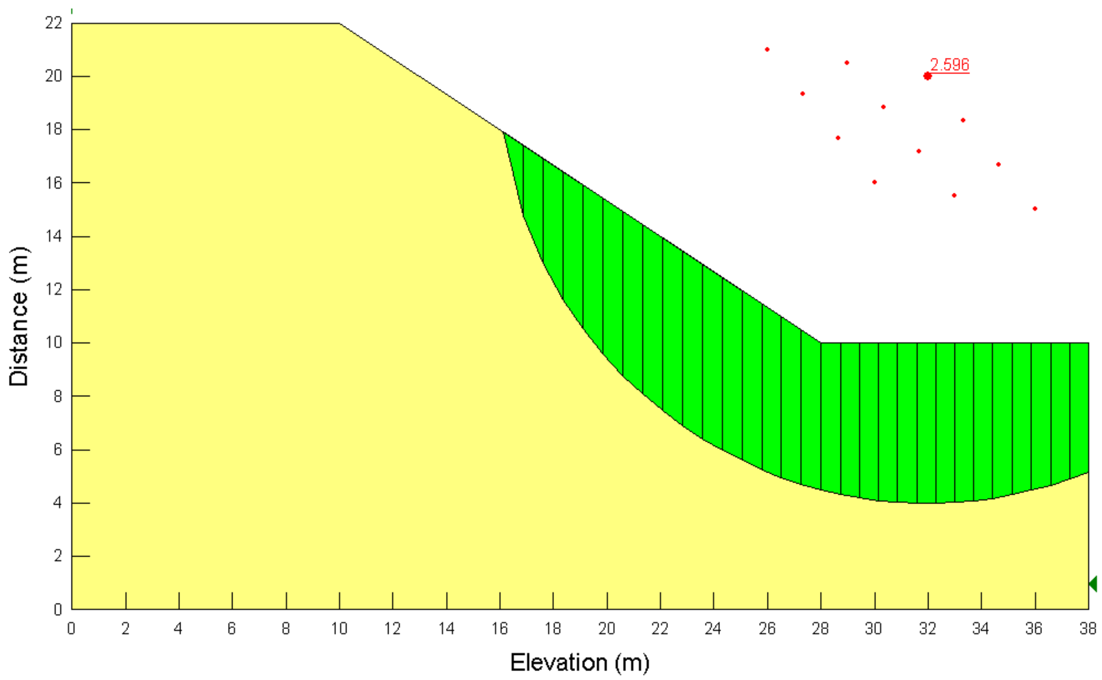

Fig.4 slope type 2 with soil type 1 under OMC condition

Table 5 Slope analytical results under loose OMC of slopes by Morgenstern–price method

			Model Types 1		Model Types 2	
Sl No	Model No	Cohesion strength (kN/m^2)	Factor of safety	Pore water pressure (kN/m^2)	Factor of safety	Pore water pressure (kN/m^2)
1	1	10	2.65	0	2.6	0
2	2	0	2.14	0	2.44	0
3	3	14	-	0	2.31	0
4	4	4	2.34	0	2.53	0
5	5	16	2.95	0	2.78	0
6	6	6	2.01	0	2.05	0
7	7	4	2.32	0	2.48	0
8	8	10	1.93	0	1.88	0
9	9	10	2.74	0	2.7	0
10	10	10	3.1	0	3.07	0
11	11	8	2.33	0	2.31	0
12	12	24	6.34	0	2.83	0
13	13	14.5	2.87	0	2.01	0
14	14	14	2.61	0	2.35	0
15	15	10	2.19	0	2.08	0
16	16	20	6.55	0	3.08	0
17	17	19	5.35	0	2.44	0

18	18	20	-	0	1.98	0
19	19	8	2.47	0	2.45	0
20	20	18	3.42	0	3.02	0
21	21	20.5	6.13	0	2.88	0
22	22	15	2.85	0	2.51	0
23	23	22	-	0	2.37	0
24	24	7	2.54	0	2.56	0
25	25	11	2.25	0	2.02	0
26	26	8	2.14	0	2.11	0
27	27	2	1.36	0	1.46	0
28	28	14	2.64	0	2.38	0
29	29	16	4.66	0	2.08	0
30	30	14	2.46	0	2.15	0
31	31	2	1.77	0	1.94	0

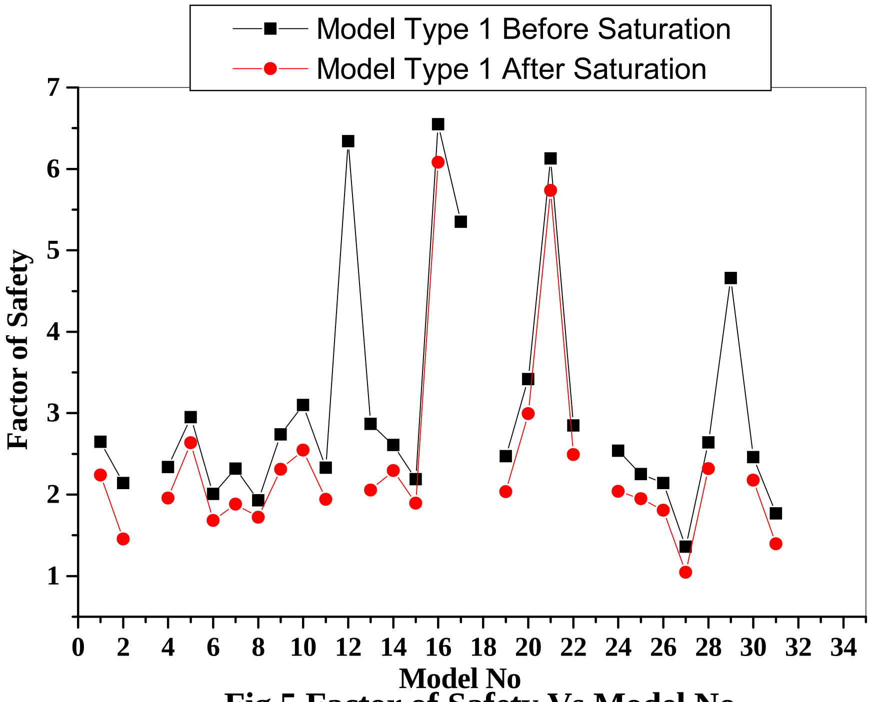

Fig 5 Factor of Safety Vs Model No

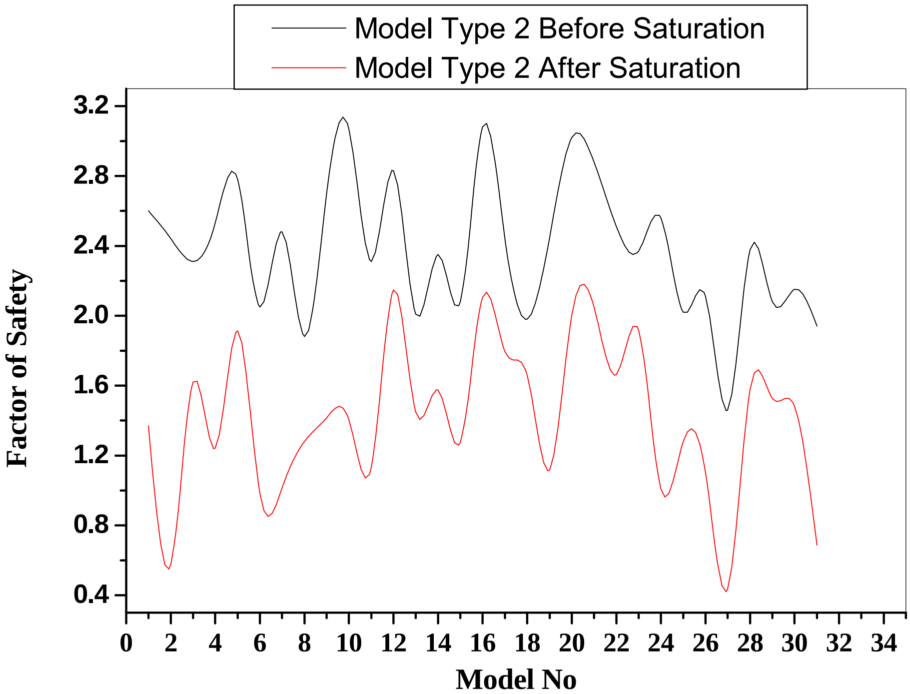

Fig 6 Factor of Safety Vs Model No

4. Conclusion

- Numerical simulation and computerize modeling of slope could be a method for theoretical understanding liquefaction and moisture affect on loose slope
- Liquefaction of slope could be mitigating if characteristics of saturated soil compare to dry soil perfectly studied
- Soil structure geometry plays one of the important factor in the design of slope
- Application of suitable material significantly reduced liquefaction
- The factor of safety has direct correlation with slope geometry and moisture
- There is direct correlation between soil mineralogy and factor of safety
- The soil mineralogy play important factor on soil mechanical properties

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NOMENCLATURE

Φ [°] = Friction Angle
C [kN/m2] = Soil Cohesion Strength
OMC % = Optimum Moisture Content %
γ [kN/m3] = Unit Weight