Seismic Response Of Root Reinforced Soil Slope At Nilgiris District Soil, Tamilnadu

R. Gobinath, G.Raja, E.Prasath, G. Sahithi, N. Prabhanjan.

Abstract: These instructions give you guidelines for preparing papers for IJSTR JOURNALS. Use this document as a template if you are Around the world, many landslides haveoccurred in hilly areas due to season and climate warming, especially seismic activity is the main factor creating tremendous failure and capable to create an unstable slope. So many researchers are working together to minimize this hazard by introducing new techniques made up of artificial material such as nailing, geosynthetic reinforcement, constructing a retaining wall, etc, here we remembering a technique called Soil Bioengineering concept which gains good and effective results by utilizing natural locally available vegetation.By thistechnique, the soil mass has to be reinforced by plant roots on slip failure area. In this study, two different plants were used to studying this slope protection technique against seismic activity such as Co-5 and Vetiver plants. A simple slope model has been designed with dimensions of 45x45x45cm and perforated holes were provided at bottom face to drain off the seepage water. This slope model filled withchosen unstable regionsoil with peculiar failure slope angle and particular plants which mentioned above areset up for plantation in a controlled temperature for the desired duration of three months. A complete seismic response is observed and pictured for Co-5 and Vetiver plants at various slope angles such as 30, 40 and 50. Every plantation period the slope is subjected to seismic study by placing the slope model ina vibrating table. During the analysis, various functions of vibration and parameters related to seismicbehaviorhave measured using a separate vibration analyzer setup and the outcome of this research to correlate the restricted displacement during seismic force using Co-5 and Vetiver plants.

Index Terms: Acceleration, Soil-Bio Engineering, Root Reinforcement, Seismic Response

1. INTRODUCTION

1.1 SOIL BIOENGINEERING:
Soil bio engineering is the concept of using the living plants/bushes for some engineering function. It is an effective tool under research for tending an unstable and eroding slope sites. Treatments using soil bioengineering systems can range from simple live staking to complex systems designed to stabilize steep, eroding or unstable slopes (Schiechtl and Stern et al. 1997). The plant materials, generally torpid cuttings, used in soil bioengineering systems germinate and take root are usually pioneering species so the vegetation establish early seral and perfect for the treatment of damaged slope sites (Polster at al. 1989). By using early seral species the restored site is re-aligned with the natural successional trajectory for the area. A discussion of plant materials that can be used in soil bio engineering projects is presented initially followed by information on the various techniques that can be used and the situations in which they are appropriate.

1.2 Seismic Behaviour of soil models:
A survey of earthquake-induced geologic disasters, such as landslides and collapses, in nilgiris district indicates that the failure has occurred due to two reasons are (1) Heavy rains that induced a high effective stress on bottom of slope (2) Earthquake activities. So to minimize that problem by adopting any geotechnical improvement methods such as soil nailing, soil reinforcement by geo synthetic, etc,. Here remembering a method called soil-bioengineering which concludes the soil has to be reinforced by plant roots. Seismically induced failure of rock slopes in mountainous regions is one of the most common geological hazards. In most cases, the landslide may cause severe traffic interruption, structural destruction and the loss of human life. Layered rock slopes are especially prone to collapse under seismic excitations, due to the relatively weak strength characteristics of discontinuities, such as joints, bedding planes and foliations. Therefore, the seismic stability evaluation of layered rock slopes becomes more important when the slope is located in an earthquake-prone area. In addition, it is also essential for the purpose of the safe design and the implementation of mitigation measures for both natural and artificial slopes (Yaqun Liu et al. 2014) (Heera et al. 2018, Sandela et al. 2017). Currently, researches on anti-seismic anchor cable mostly focus on prestressed anchor cable, anchor pile, anchor frame and other supporting structures, mainly involving slope dynamic magnification factor, slope failure mechanism, seismic influence coefficient and the loss of prestress (Ming Xu et al.2018). At present, the conventional pseudo-static method is still widely used in seismic slope stability analysis, and has even been incorporated into specifications in some regions, due to its simplicity and feasibility (Baker R and Garber M. 1978 and Feng ZY et al. 2016). Although the pseudo-static approach is simple and practical, it has some inherited limitations, mainly due to some of the assumptions it makes, including: (1) the slope is an absolutely rigid body, and the accelerations for both the slope body and ground are the same; (2) the pseudo-static force remains constant; and (3) the failure of the slope will only occur when the factor of safety is less than one. However, it is well known that the slope is a deformable body rather than a rigid one(Yaqun Liu et al. 2014) (Shaik et al. 2017, Gobinath et al. 2019). Limit analysis is a powerful mathematical tool that provides rigorous lower and upper bounds to the exact collapse load or the factor of safety. Chen used the kinematic approach of limit analysis to determine the critical height of slope for a rotational failure mechanism under plane strain conditions (Ting-Kai Nian et al. 2016) (Manepalli et al. 2019, Raju et al, 2018) The New mark method and quasi-static methods do not take into account the time-frequency-amplitude characteristics of the earthquake waves simultaneously, and also the dynamic slope behavior. Although the numerical simulation methods can consider the time frequency-amplitude characteristics of the earthquake waves comprehensively, the operation of numerical simulations is often complex. If lacking the verification with other methods, the accuracy of numerical analysis results could be suspicious. In order to overcome some of the disadvantages of the exiting methods for slope stability evaluation, anew time-frequency analysis method, which takes into account the time-frequency-amplitude characteristics of the earthquake waves simultaneously (Gang Fan et al. 2017) ((Sandela et al. 2017) A

shaking table test example is worked out to illustrate the application of the proposed time-frequency analysis method to a bedding rock slope. The instantaneous seismic safety factors of all bedding planes are calculated based on the time-frequency analysis method proposed in this research. The seismic safety factor changes significantly over time, and the seismic safety factor of the upper part of the bedding rock slope is smaller than that of the lower part of the bedding rock slope. Hence the upper part of the bedding rock slope is more vulnerable to seismic damage(Gang Fan et al. 2017, and Seed HB. 1973).

2. METHODS

2.1 Study Area Description:

This research is conducted in The Nilgiris district situated in Tamilnadu state, India, it literally means blue hills or in Tamil, it's called as "Neelamalai", the name originated owing to the blue colored haze of considerable quantum. This hill is surrounded by Kerala and Karnataka states on West and Northern side, by Coimbatore district on the Eastern side, it lies between North Latitude between 11o 30' 00".12 and 19o 30' 00".42 and East Longitude between 76o 29' 52".55 and 76o 36' 00".21. One of the peaks, Doddabetta, has an altitude of 2,595 Meters is the highest peak in this area. Some major towns like Kotagiri, Coonoor, and Gudalur also lie at a height of 1,983, 1858 and 1,117 meters above mean sea level respectively. The district has numerous waterfalls and almost between every pair of mountain runs a river or a stream. The Nilgiris district covers an area of 2,543 square kilometers, in that gross area under cultivation is nearly 77,520 Hectares.

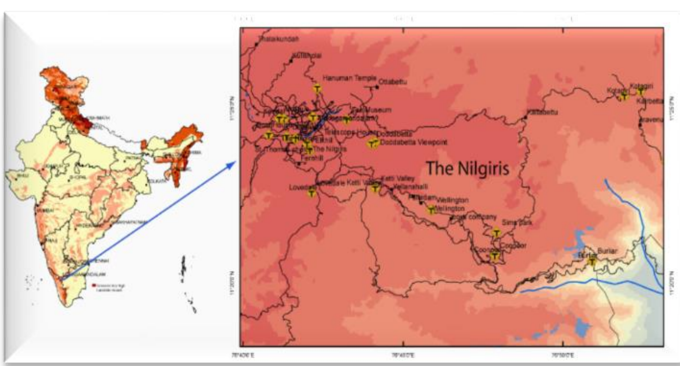


Fig.1 *Described site at Nilgiris district*

Rainfall in the district is bountiful and its affected majorly due to monsoons from southwest and northeast, data available shows that more rainfall occurs during southwest monsoon (up to 50%) than northeast (40%).

2.2 Field Investigation:

Site inspections were conducted for two consecutive years during monsoon and in the dry season to ascertain the following parameters. Field density in various locations – It is found to be varying between 1200 kg/cum to 1450 kg/cum while sampling. Sampling was done in 49 places. The water content of soil during the rainy season- It is found to be varying from 12% to 43%. Mostly in the areas where small to medium slides occurred the water content ranged from 18% to 31%. Soil size has mostly found to be fine-grained soil with full of clay content.

2.3 Systematical setup of Vibrating system:

A complete setup of vibrating system (Fig.2) has been designed for examining a seismic response of soil slope at varying angles from 40 to 60. A simple vibrating table is placed on a concrete bed and on top of working place of table having a wide area to accommodate the soil slope model. Slope model is having a dimensions of 45x45x45cm as a nearly triangular shape and having a small channel at bottom to collect a seepage water drain off from the soil media while soil getting saturate. A vibration analyser is performing in between of vibrating table and computer to compute the motion of equation. An input end of vibration analyser is connecting with a vibrating table and the output end is connected to the computer USB end.

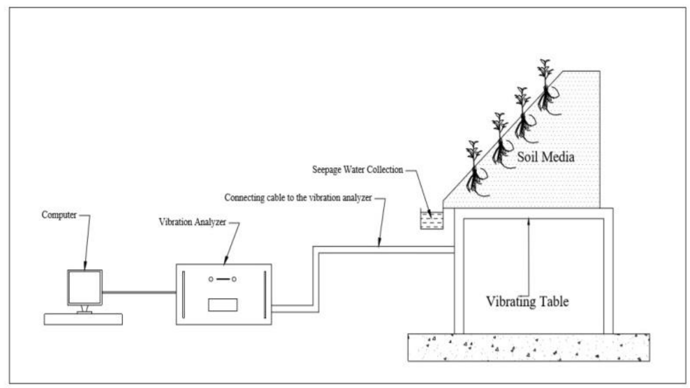


Fig.2 *A systematical setup of vibrating system*

2.4 Plantation on soil slope:

A quantum of soil mass was collected from landslide affected area during the site visit on monsoon season of 2015. For the soil-bioengineering study, we selected two plants for the reinforcement is Co-5 and Vetiver. Those plants are selected as basis of soil fertility properties and native plants of nilgiris district. The plants are allowed to grow up on soil slope with various angles such as 40, 50 and 60 in a laboratory.
Fig.2 represents the vetiver plantation on soil with various slope angles from 40 to 60.

2.5 Vibration Analysis for naturally reinforced soil slope model:

After one month base period of plant, the slope model is allowed to perform a vibration analysis as

Fig.3 *Plantation on soil slope*

per planned procedure. A single slope model has kept on vibrating table and the seepage water in the channel has been removed before the test to be perform.

Fig.4 *Complete setup of vibration analysis*

Similarly the vibration analyser and computer is connected with complete calibration as shown Fig.3.

3. ANALYSIS AND RESULTS:

3.1 Geotechnical Properties of soil:

The results of various geotechnical properties of soil sample is manipulated and tabulated in table.1 and followed a test procedure as per IS 2720 series. During the field investigation, filed moisture content of soil is determined by using a Rapid moisture meter (Calcium Carbide Method). Based on the laboratory investigation, the collected soil sample to be classified as Inorganic clay with low plasticity. This is classified from the plasticity chart of IS classification for fine-grained soil. Similarly based on the consistency, it is said to be a very soft clay. The plasticity of the soil varies from 30 to 36 %, so it may contain both clay and silt particles in moderate. If the soil having high clay particles, the apparent interaction area to the root is to be high.

Table 1 Basic *Properties of Soil*

Properties	Result	IS code referred (IS Series)
Uniformity coefficient (Cu)	4.848	1498:1970
Coefficient of curvature (Cc)	1.065	1498:1970
Plasticity index (%)	13.37	2720(v):1985
Liquidity index (%)	59.83	2720(v):1985
Consistency index (%)	159.83	2720(v):1985
Bulk density (kg/m^3)	2120	2720(vii):1980
Dry density (kg/m^3)	1930	2720(vii):1980
OMC (%)	10	2720(vii):1980
Permeability (mm/sec)	0.067	2720(17):1986
Cohesion (kN/m^2)	5	2720(39):1977
Angle of Internal Friction	33°	2720(39):1977
Shear strength (kN/m^2)	135.3	2720(39):1977

3.2 Seismic Behaviour of Co-5 Plant root reinforced soil:
Generally, during an earthquake the seismic waves (vibration) is acting at shortest duration only, but here we have applied the vibration until the soil mass get failure. So the elapsed time is not equal to the duration of earthquake occurred in past decades.

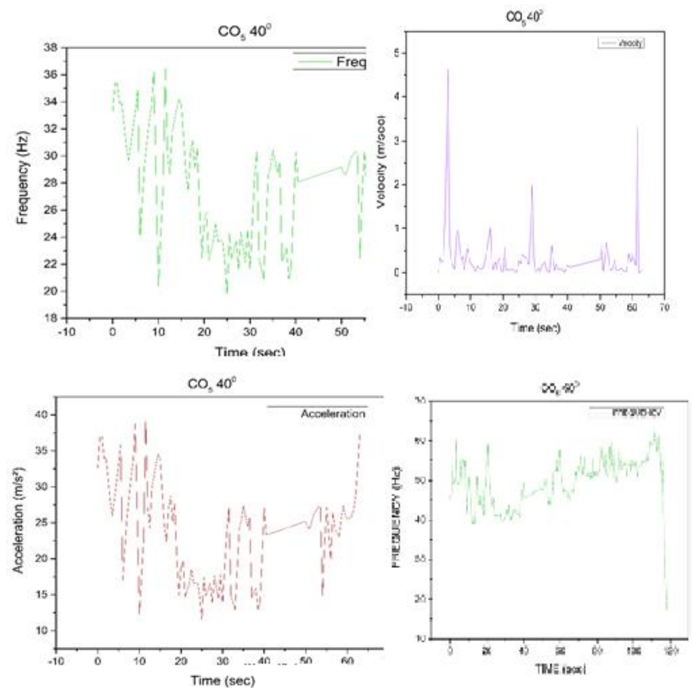
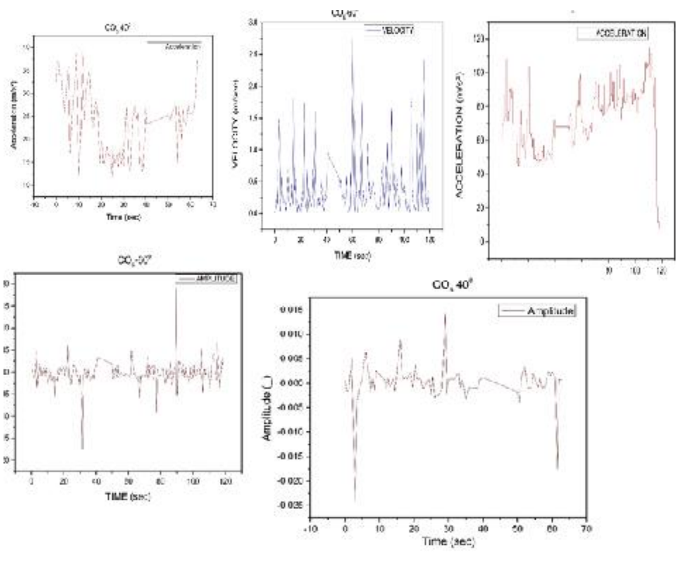


Fig.5 *Seismic Parameters of Co-5 Plant Root reinforced soil at angle of 40o (a) Frequency variation (b) Acceleration variation (c) Velocity variation (d) Amplitude variation*

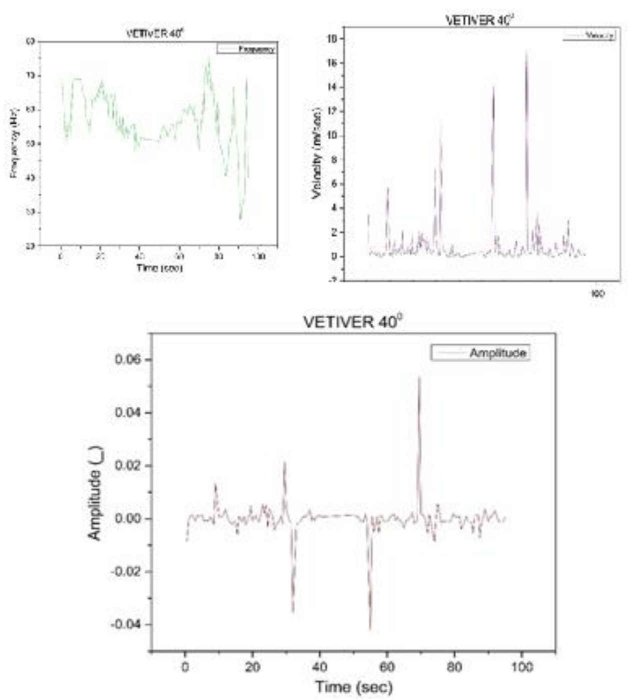


(d)

***Fig.7** Seismic Parameters of Co-5 Plant Root reinforced soil at angle of 60o (a) Frequency variation (b) Acceleration variation (c) Velocity variation (d) Amplitude variation*

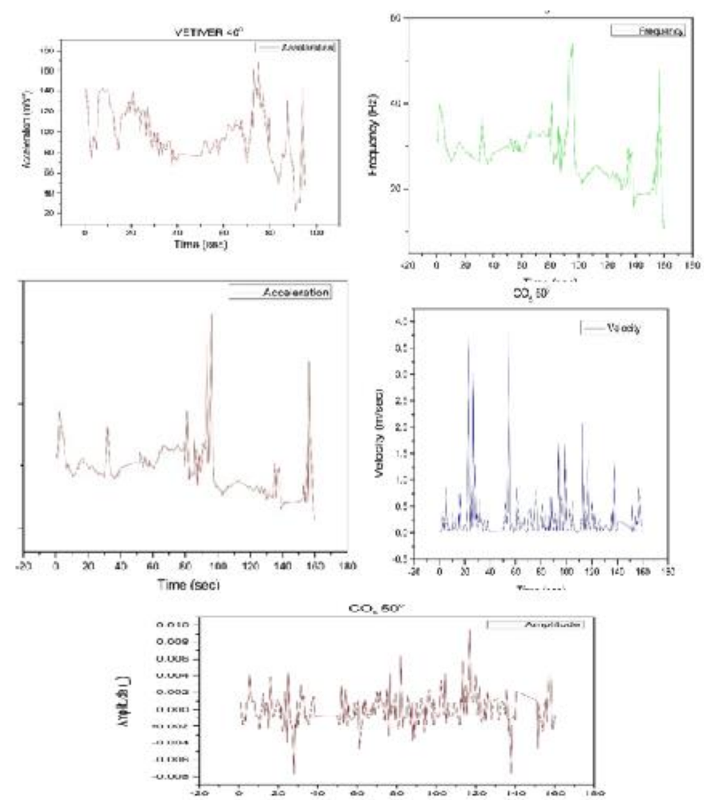
3.3 Seismic Behaviour of Vetiver Plant Root Reinforced soil:

During the vibration analysis, the various functions and parameters of vibration such as acceleration, frequency, velocity, amplitude and maximum displacement is measured with help of digital vibration analyser.



(d)

***Fig.8** Seismic Parameters of Vetiver Plant Root reinforced soil at angle of 40o (a) Frequency variation (b) Acceleration variation (c) Velocity variation (d) Amplitude variation*



(d)

***Fig.6** Seismic Parameters of Co-5 Plant Root reinforced soil at angle of 50o (a) Frequency variation (b) Acceleration variation (c) Velocity variation (d) Amplitude variation*

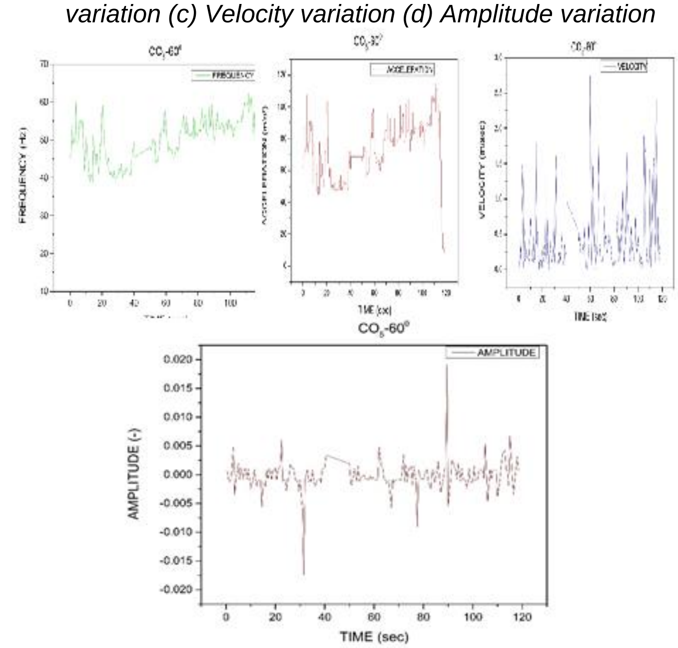


***Fig.7** Seismic Parameters of Co-5 Plant Root reinforced soil at angle of 60o (a) Frequency variation (b) Acceleration variation (c) Velocity variation (d) Amplitude variation*

3.3 Seismic Behaviour of Vetiver Plant Root Reinforced soil:

During the vibration analysis, the various functions and parameters of vibration such as acceleration, frequency, velocity, amplitude and maximum displacement is measured with help of digital vibration analyser.

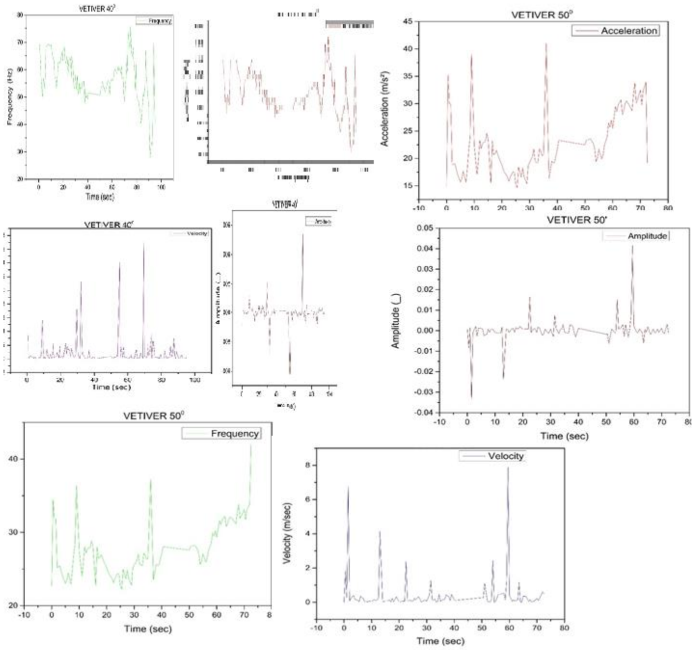


Fig.9 *Seismic Parameters of Vetiver Plant Root reinforced soil at angle of 50o (a) Frequency variation (b) Acceleration variation (c) Velocity variation (d) Amplitude variation*

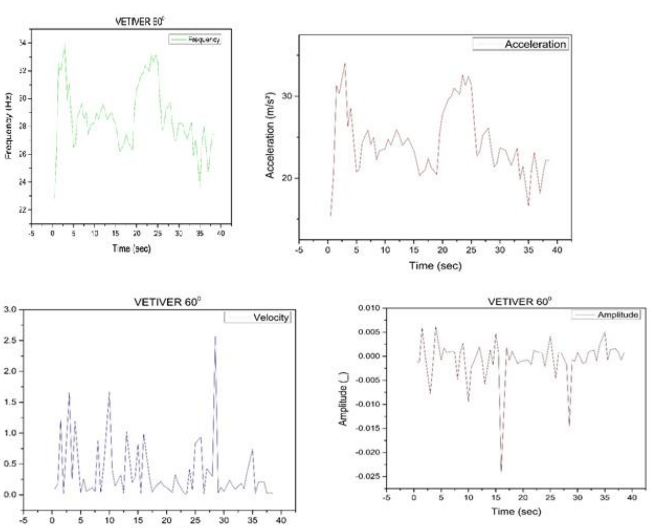
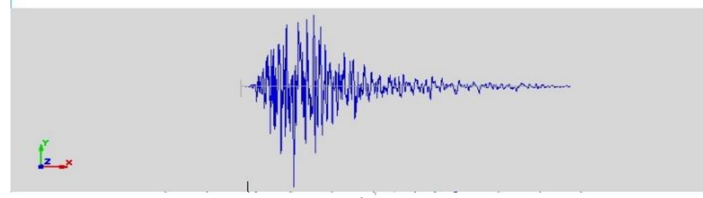


Fig.10 *Seismic Parameters of Vetiver Plant Root reinforced soil at angle of 60o (a) Frequency variation (b) Acceleration variation (c) Velocity variation (d) Amplitude variation*

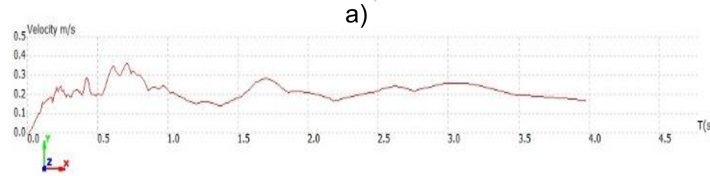
4. DYNAMIC ANALYSIS IN SOFTWARE TOOL:

4.1 Dynamic Response of unreinforced soil:

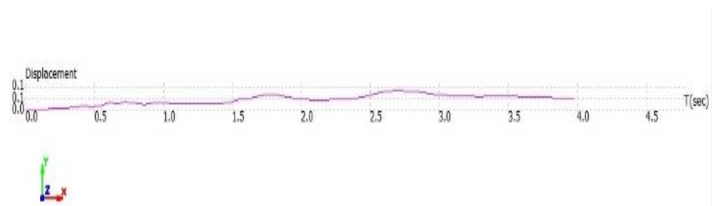
A soil model is created with 8m flat surface at upstream side and 5m elevation at downstream side in Geostru software. The engineering properties of soil has imported to model and 2015 seismic data of nilgiris district is imported.



a)



B)



C)

Fig.11 Seismic *data of Nilgiris district in 2015*
(a) Seismograph (b) Velocity Spectrum (c) Displacement Spectrum

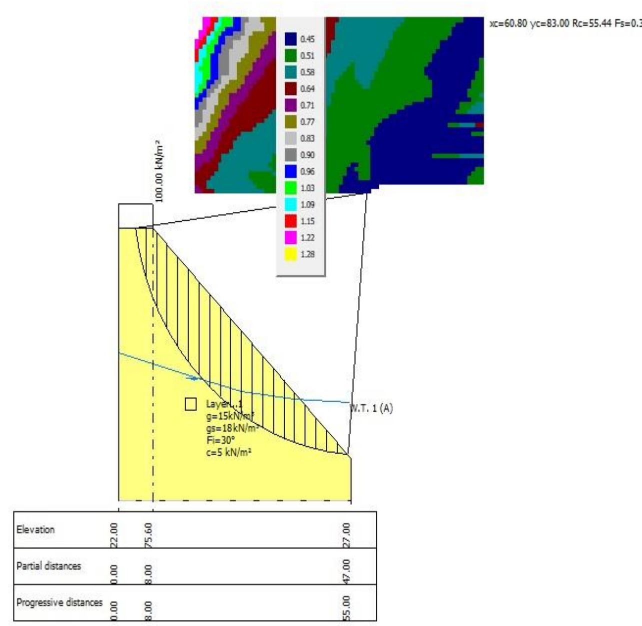


Fig.12 *Dynamic response of unreinforced soil model with FOS at an angle of 40^{o}*

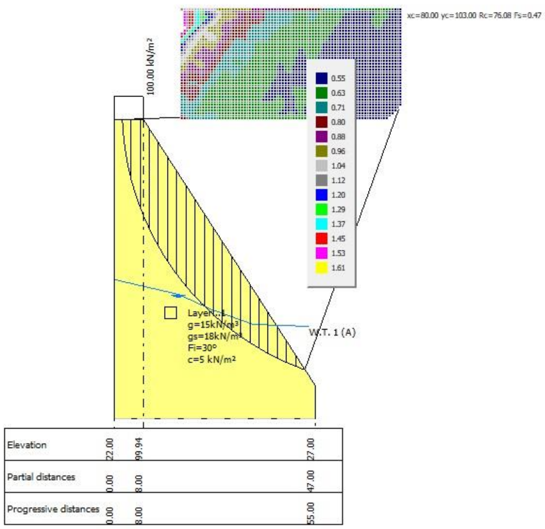


Fig.13 *Dynamic response of unreinforced soil model with FOS at an angle of 50°*

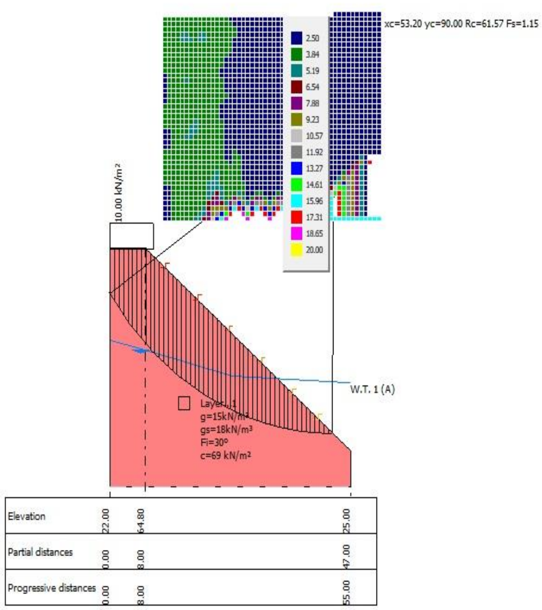


Fig.14 Dynamic *response of unreinforced soil model with FOS at an angle of 60o*

4.2 Dynamic Response Root Reinforced soil:

During the analysis, a slip surface is divided into 30 slices and 500 centre grids are divided. The color legend represents the variations of factor of safety of slope along a centre grids. Lines on bottom of slope is shows the elevation and distance of slope model. The water table level is applied as varying head with respect to distance of slope.

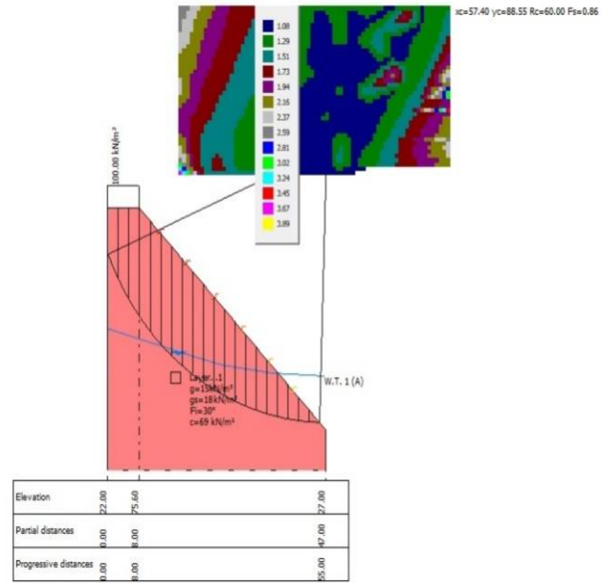


Fig.15 Dynamic *response of Co-5 Plant Root Reinforced soil model with FOS at an angle of 40°*

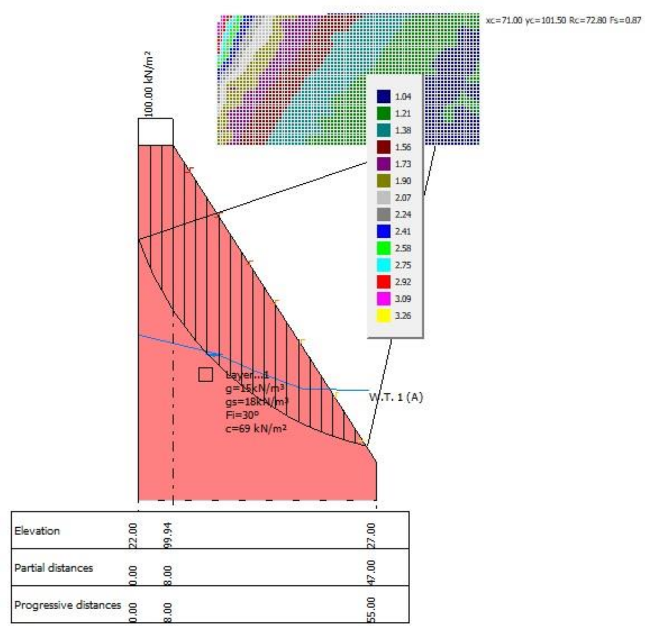


Fig.16 *Dynamic response of Co-5 Plant Root Reinforced soil model with FOS at an angle of 50°*

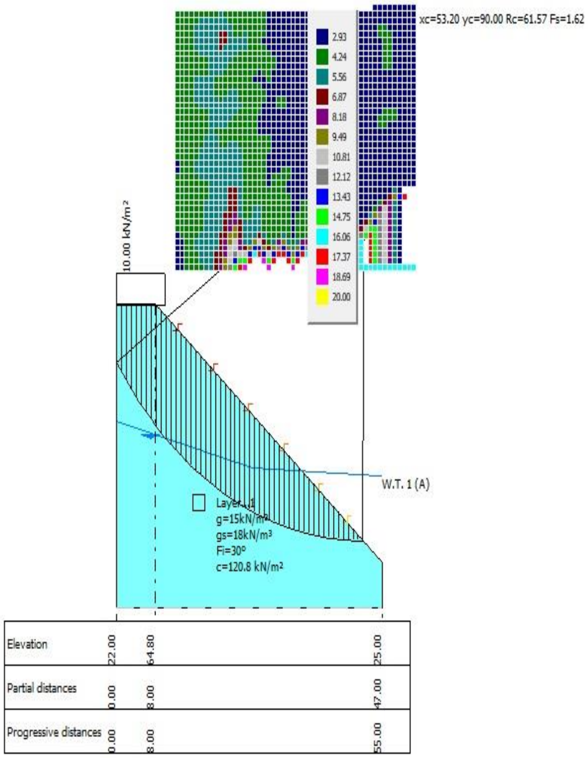


***Fig.17** Dynamic response of Co-5 Plant Root Reinforced soil model with FOS at an angle of 60^o*

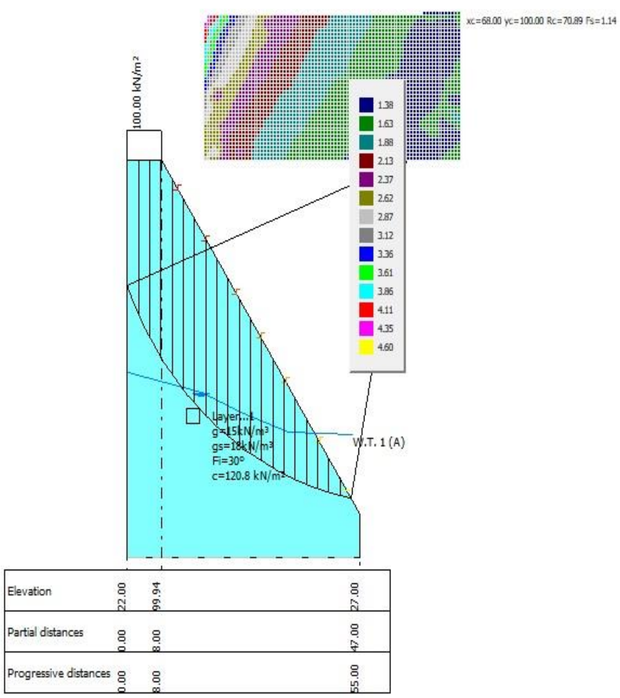


***Fig.18** Dynamic response of Vetiver Plant Root Reinforced soil model with FOS at an angle of 40^o*

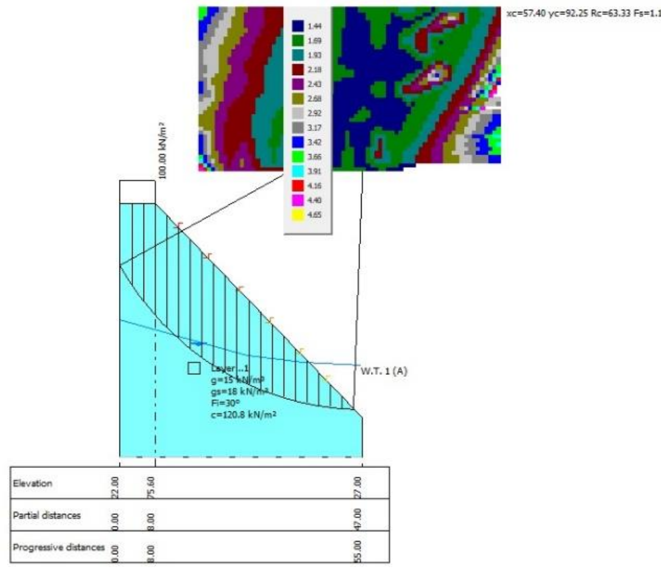


***Fig.19** Dynamic response of Vetiver Plant Root Reinforced soil model with FOS at an angle of 50^o*

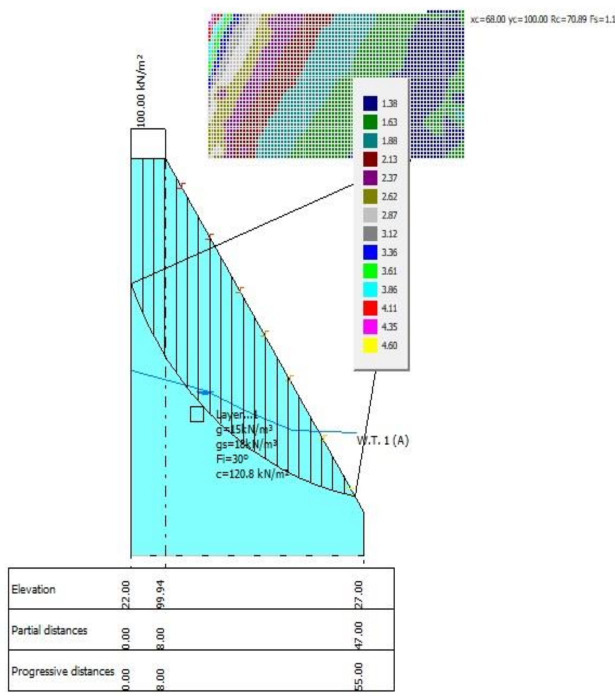


***Fig.20** Dynamic response of Vetiver Plant Root Reinforced soil model with FOS at an angle of 60^o*

After the modelling, slope model is allowed to perform static and dynamic loading. Then a various parameters of stability such as FOS, Critical Acceleration and Critical Dynamic factor is observed and tabulated in Table.2.

Table.2 *Dynamic Response of complete study*

Description	Angle	FOS	Critical Acceleration	Critical Dynamic Factor
Unreinforced soil	40	0.5	0.01	0.001
	50	0.39	0.01	0.001
	60	0.47	0.01	0.001
Co-5 Root Reinforced soil	40	1.15	2.855	0.291
	50	0.86	1.923	0.196
	60	0.87	0.812	0.081
Vetiver Root Reinforced soil	40	1.62	4.915	0.501
	50	1.19	4.153	0.424
	60	1.14	1.804	0.182

CONCLUSION:

Both laboratory and software analysis has performed for unreinforced and root reinforced soil for three angles. As mentioned early, the vibration analysis is performed until the soil mass get failure. Normally the fine roots are giving more shear strength and less drainage properties in a static condition. But in dynamic loading the soil mass does not behaving like that, so we observed elapsed time failure in a laboratory investigation. Similarly in software analysis, the seismic data of 2015 earthquake is imported and observed various factors such as FOS, Critical Acceleration and Critical Dynamic factor. Based on the laboratory and software analysis vetiver plant root giving more stability to the slope than the Co-5 plant. Even Co-5 plant root also giving minimum stability compare to vetiver, so Co-5 plant also used for reinforcement at 40o angle slope. Vetiver plant can used for any angle we analysed for the reinforcement in slope.

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