# OVERBURDEN DUMP SLOPE STABILITY: A CASE STUDY AT COAL MINE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Mining Engineering

By

**Purna Bahadur Rai** **Sudeep Mahapatro**

**109MN0484** **109MN0590**

Department of Mining Engineering
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Under the guidance of

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**CERTIFICATE**

This is to certify that the thesis entitled "**OVERBURDEN DUMP SLOPE STABILITY: A CASE STUDY AT COAL MINE**" Submitted by Sri Sudeep Mahapatro, Roll No. 109MN0590 and Mr. Purna Bahadur Rai, Roll No. 109MN0484 in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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Date:

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**Sudeep Mahapatro**

**Purna Bahadur Rai**

## ABSTRACT

Slope stability of overburden dumps plays as integral part of opencast mine project throughout the operation process. Waste dumps always have steep angled slopes as the waste has been tipped over from the top of the dump in a continuous and progressive manner. For new landfill it is often desirable to design steep slopes as it can accommodate the maximum amount of waste possible. The heavy machinery implanted for the extraction and transportation of wastes in the opencast mine whose management is of prime importance. The problems relating to overburden dump slope stability is catching attention for safe working in adverse natural constraints.

This paper examines the influence of various parameters such as slope height, slope inclination, interfacial shearing resistance on the dump deposit. The analysis cover analysis of various sections of the waste dumps from the mine including material properties, strength values, bench height and angle. The evaluation of slope stability analyses in geotechnical analyses in geotechnical engineering has followed closely developments in soil and rock mechanics as a whole. Most of the design methods are purely based on field experience, followed by sound engineering judgment. During the last few decades, the concepts of slope stability analysis have emerged within the domain of rock and geotechnical engineering to address the problems of design and stability of dump slopes.

# CHAPTER – 1

# INTRODUCTION

## 1.0 Introduction.

The removal of overburden is the first step in a coal winning operation, so as to expose underlying coal for excavation. The overburden material being a waste and nonmarketable product, it is removed and dumped safely and economically. The primary aim for construction of overburden dump is to provide an effective stable working surface for the dump deposit.

The failure of a dump mass of soil located beneath a slope is called a dump slide. It involves a downward and outward movement of the entire mass of soil that participates in the dump slope failure. Dump slide may occur in almost every possible manner, slowly or suddenly and with or without any apparent provocation. Usually, slides are due to excavation or to undercutting the foot of an existing dump slope. However, in some instances, they are caused by a gradual disintegration of the structure of the overburden dump. Optimization dumping ensures saving in ground and do not have any chance of sliding which results in accidents in future. Low height and flat dumps could be ideal from the points of stability; however, these would not only occupy lot of ground space but also prove very expensive. Hence, a balance needs to be maintained between maximum slope with minimum possible ground space to be occupied while ensuring that dumps do not slide and causes any untoward incident/ accidents. Overburden dumps can be external dumps created at a site away from the coal bearing area or it can be internal-dumps created by in-pit dumping concurrent to the creation of voids by extraction of coal. Practice of dumping overburden in the external dumps has some serious problems. Foremost among them are requirement of additional land which involves very high transport and re-handling cost. Therefore, it increases the cost of coal production substantially, stability and reclamation at the site. It is not possible to eliminate the option of external dump concepts completely even if we practice in-pit dump practice. The combination of external dumps and internal dumps shall substantially reduce the required land. As a result, it shall reduce the surface land requirement significantly which is very difficult task to arrange in any area due to the growth of population, forest cover and associated problem.

## 1.1 AIM OF THE STUDY

The primary purpose of the slope stability analysis is to contribute to the safe and economic design of mine overburden dump. Dump Slope stability evaluation are concerned with identifying critical geological, material, environmental and economic parameters that will affect the project. Wardha valley has huge coal reserve. Based on IBM (2012) report it has a total reserve of 6.2 billion tonnes. However, this region is very prone to dump stability of the geological set up of this region as the area is covered by black cotton soil, which is expansive in nature (Katti, 2002). In Wardha valley, dump failure was also reported due to improper geometry of the dump (Kainthola et al., 2011). Therefore, the aim of this project work is to study the stability of dump slope with various geometry using geomechanical properties of dump forming material through numerical modeling at Mungoli opencast coal mine, which is located in Wardha valley.

# CHAPTER- 2

# LITERATURE REVIEW

## 2.1 Dump failure Mechanism.

Dump failure occurs when the dump forming materials move down the dump slope. This kind of failure occurs in end-dumped embankments and is best evaluated by the equations describing the stability of an infinite slope. If sufficient water enters the slope and flows parallel to the surface a hallow flows slide may occur.

Overburden dump placed on stable or flat ground of competent soil are least likely to fail. However if the ground is covered by thin layer of weak material and aquifer, base failure may occur. If the ground is inclined, base failure is most likely to occur. This mode may occur in both end-dumped and layer placed embankments. Block translation is likely to occur where a dump is formed on inclined ground and the soil cover is relatively thin and weak. Such failures are initiated by the presence of water tables in the embankment, earthquakes or the decay of organic materials beneath the dump. Circular arc failure occurs when the dump is formed on the competent foundation and the dump materials containing significant percentage of fine grain soil (Sikora et.al, 2004)

## 2.2 Factors controlling the dump failures:

Various factors are responsible for the instability of dump and major factors are given below as described in (Das, 2008).

- ✓ Seepage of water from dump to slope.
- ✓ Changes in cohesion of interface materials.
- ✓ Changes of stress.
- ✓ Ground vibration by blasting and earthquake.
- ✓ Dynamic impact/force caused by plying dumpers, Heavy Earth Moving Machineries, rollers, etc.
- ✓ Dump slope angle.
- ✓ Natures of the dump materials.

- ✓ Degree of compaction.
- ✓ Dump height.
- ✓ Flow of mud/surface erosion due to rapidly moving stream of water borne soil.
- ✓ Surface slip due to presence of dry and non-sticky materials in the overburden dump.
- ✓ Wash down of fines within the dump due to deep erosion and formation of gullies. It generally happens during the rainy seasons which causes voids in the dumps and lead to slope failure.
- ✓ Rotational slip due to decrease in the shear strength of materials which is due to the decrease in frictional and cohesive components especially when seepage water pressurize dump materials causing slope failure.

**2.3 Basic concept of dump slope Stability:**

Three principle stresses, namely, $\sigma_1$, $\sigma_2$ and $\sigma_3$ are considered at any point in a saturated soil mass. Slope materials have tendency to slide due to shearing stresses created in the soil by gravitational and other forces like water flow, tectonic stresses, seismic activity, etc. This tendency is resisted by the shear strength of slope materials expressed by Mohr Coulomb theory as given below:

$$\mathbf{S = c + \sigma_n \tan \varphi}$$

Where, S= Total shear strength of the soil.

c= Total cohesion of soil.

$\sigma_n$= Total Normal stress.

$\varphi$= Total angle of internal friction.

If there is pore water pressure, then effective shear resistance will be:

$$\mathbf{S' = c' + (\sigma_n - u) \tan \varphi'}$$

Where S′=drained shear strength of the soil
c’=effective cohesion of the soil normal stress
$\sigma_{n=}$ normal stress
u=pore water pressure
$\varphi$’=angle of internal friction in terms of effective stress

Practically all dump slope stability analyses are based on the concept of limit equilibrium. A state of Limit equilibrium is assumed to exist when the shearing resistance along an assumed failure surface equals the shear strength of the dump material or when factor of safety equals unity. Figure1 shows the geometry of dump slope failure where the different forces are shown (Abramson et al., 2002).

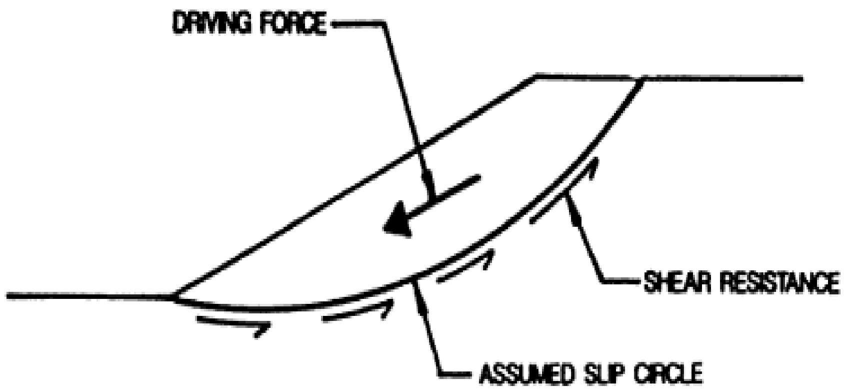


Figure 1 Geometry of dump slope failure

From the equation below:

$$\tau = \frac{S}{FOS}$$

Where, $\tau$= Shearing stress along the assumed failure surface.
S= shear strength of the soil.
FOS= Factor of safety.

Therefore from above equation we can say that:

$$FOS = \frac{c + \sigma n \tan\phi}{\tau}$$

$$FOS = \frac{\text{Resisting Force}}{\text{Driving Force}}$$

So factor of safety can be defined as resistance force divided by driving force. If the safety factor is greater than 1 then the slope is assumed to be stable. However, for long term stability it must be 1.2 to 1.4 in open cast mine (Wyllie and Mah, 2004).

There are various dump failure modes as described by Hardygóra et al, (2004) and shown in the Figure 2. Surface or edge slide occurs when materials moves down the slope. This mode of failure is most likely to occur in end-dump embankments and is best evaluated by equations describing the stability of an infinite slope. If sufficient water enters the slope and flows parallel to the face, a shallow flow may occur. Base Failure usually occurs if the ground is inclined and when the base ground is covered by a thin layer of weak dumping material. This failure mode may occur both in layer placed embankments and end-dump. Block Translation will occur where a dump is formed on inclined ground and the soil is relatively thin and weak. Most often high water tables in the embankment, earthquakes or the decay of organic material beneath the dump may induce such failure. Circular are Failure does occur if the dump if formed on a competent foundation and the dump material contains a significant percentage of finer grain soil. It may also develop through a deep foundation soil deposit of fin grained soils.

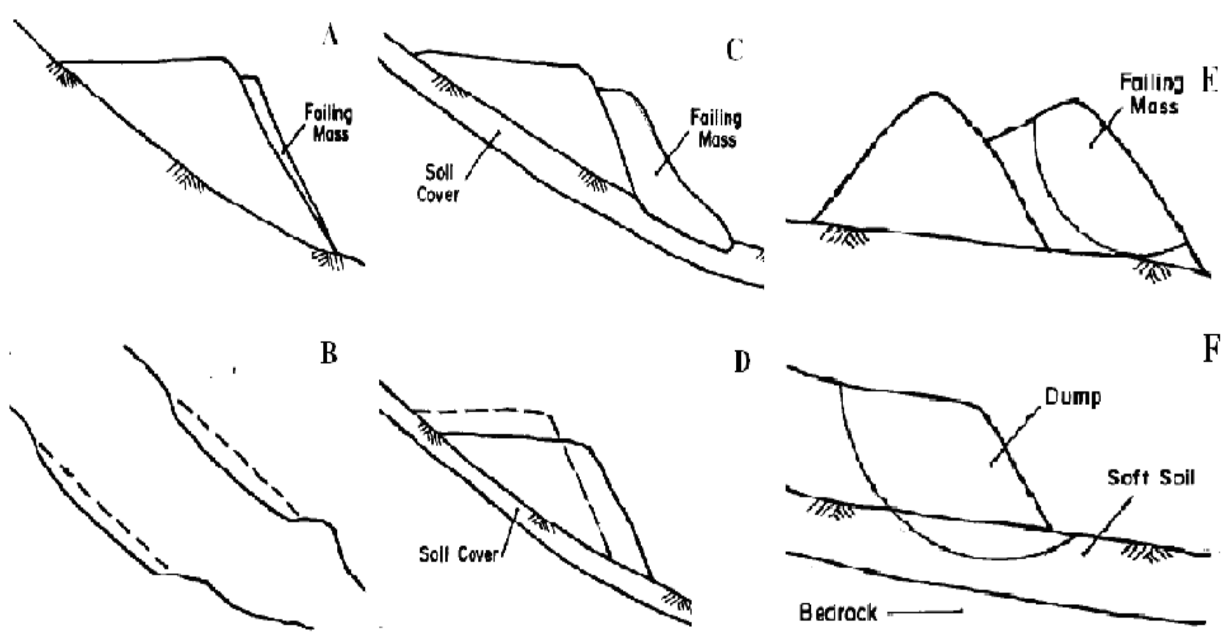

Figure 2 (A) Surface or edge slide, (B) Shallow flow slides, (C) Base failure, (D) Block translation, (E) Circular arc failure, (F) Foundation circular failure.

## 1.2 STUDY AREA

Mungoli opencast mine, Wani Area, is a part of Mungoli Nirguda block, which forms a part of the south western part of the western limb of the Wardha Valley Coalfield. Wardha Valley Coalfield covers a vast area of around 4000 $km^2$ within the district of Chandrapur and Yavatmal in Maharastra. Mungoli opencast mine started in the year of 1993 to 1994. Mining activities in Mungoli opencast mine is going on using shovel-dumper combination with nearly 3.2 million ton annual production.

Generally coal seams occur almost in the middle part of Barakar Formation. The lithology of Barakar Formation encountered in the boreholes are represented by gray to white, fine to coarse grained sandstones, thin clay bands, shale, intercalation of shale and sandstone, sandy shale, shaly sandstone, carbonaceous Shale, shaly coal and coal. The most potential coal seam i.e composite seam occur in this formation .This formation is unconformably overlain by Kamthi Formation. The total thickness of the Barakar rocks as encountered in the boreholes varies from 14.10 m to 256.92 m. The geological succession as well as thickness range of different formations in the block based on borehole data is given in Table 1.

Table 1 Geological succession at Mungoli Opencast mine, Wani area

| Age | Formation | Thickness (m) | | Lithology |
|---|---|---|---|---|
| | | Minimum | Maximum | |
| Recent /Sub-Recent | Detrital Mantle Soil | 0.50 | 21.35 | Black Cotton soil /Sandy soil |
| Upper Permian to lower Triassic | Kamthi | 3.50 | 147.60 | Yellow to brown, fine to coarse grained sandstone, shale and variegated clays. |
| ……………………………………Unconformity……………………………….. | | | | |
| Middle | Motur | 18.99 | 238.1 | Medium to fine grain |

| | | | | |
|---|---|---|---|---|
| Permian | | | | variegated sandstone, variegated clays and shale. |
| Lower Permian | Barakar | 14.10 | 256.92 | Grey to white, fine to coarse grained sandstones, thin clay bands, shale, interaction of shale and sandstone, sandy, shale, shaly sandstone, carb. Shale, shaly coal and coal. |
| Upper carboniferous to lower Permian | Talchir | 4.20 | | Green shale |

The sequence of coal seams encountered in boreholes drilled in Mungoli Nirguda Block in ascending order is furnished in Table 2. It is seen from the above table that generally seam sections encountered in Mungoli Nirguda Block are potential and persistent in nature.

The general strike in the eastern part of the Block is nearly E-W and NE-SW and in the western half it is NW-SE and WNW-ESE. It has western dip and varies from 7° to 9°. The corresponding gradient varies from 1 in 8 to 1 in 6. The general strike of the coal seam with in the project area is N14°E – S14°W. Gradient of coal seam within the project area is 1 in 10 which flatters towards the sub-crop side. The dip of the coal seam is S76°W. The area has two sets of prominent vertical joints with strike nearly N50°W – S50°E (Figure 2) and S30°W – N30°E. Strike of the prominent vertical cleat is N80°W – S80°E (Figure 3). One gravity fault was found on western side of the mine with strike.

Table 2 Sequence of coal seam at Mungoli Opencast mine, Wani area

| **Coal Seam/Parting** | **Thickness range (m)** | | **Generalized Thickness Range (m)** | |
|---|---|---|---|---|
| | **Mininum** | **Maximum** | **Mininmum** | **Maximum** |

| | | | | |
|---|---|---|---|---|
| Section-A<br>Parting<br>Section-B<br>Parting | 0.21<br>0.32<br>0.08<br>0.3 | 4.68<br>5.49<br>3.75<br>7.93 | 0.66<br><br>0.51 | 3.34<br><br>3.12 |
| Section-C<br>Parting<br>Sectio-D | 0.24<br>1.44<br>5.07 | 4.43<br>8.00<br>12.01 | 0.53<br><br>6.07 | 4.43<br><br>11.07 |
| Composite Sections-A+B+C+D | 10.07 | 19.28 | 11.16 | 17.48 |

## 2.4 Precaution taken for dump failures

Das (2008) mentioned various measures that reduce the dump failure and described below:

a) A Cross section of the strata (1 in 1250) under the dumps showing thickness, fault planes and geotechnical characteristics of strata including shear strength, angle of internal friction of dump material.

b) An accurate mine plan showing all mine workings, previous landslides, springs, water courses and other natural and other topographical features.

c) Plan and sections covering gradient of land, designed height, contour and boundaries of the dumps.

d) The angle of slope of overburden dumps should be less than the angle of repose of the materials and should not exceed 37.5 degree from the horizontal.

e) The dump height exceeding 30 m shall be benched in such a manner that no bench exceeds 30 m in height and the general slope shall in no case exceed 1 vertical 1.5 horizontal.

f) Toe of any dump shall not be permitted to approach any railway lines/public road, building or any other permanent structure not belonging to the owner of the mine.
g) A suitable fence should be created around the toes of every dump so that no unauthorized person can approach any dump for under digging during collection of coal or stone.
h) The coal ribs may be left on the floor in case of internal dump which will give a good stability of the dumped materials.

Blanco et al, (2008) mentioned the importance of coir matting in dump stability. The coir matting is widely used in the dump slope stabilization and prevention of dump failures. It is a biodegradable coir geo-textile made of coconut fiber or husk. It facilitates new vegetation by absorbing water and preventing topsoil from drying out. Seeding or plantation is done after blanketing the coir matting on the dump slope. They provide dump soil good support allowing natural vegetation to become established. The Figure 3 (a) shows the typical coir matting in dump slopes. The Figure 3 (b) shows the process of coir matt blanketing on the dump slopes. First the dump soil slopes are maintained properly. The seeding is done next. After that the coir matt are placed on the dump with proper anchor. Then the seedling will soon cover the dump with vegetation which stabilizes the dump.

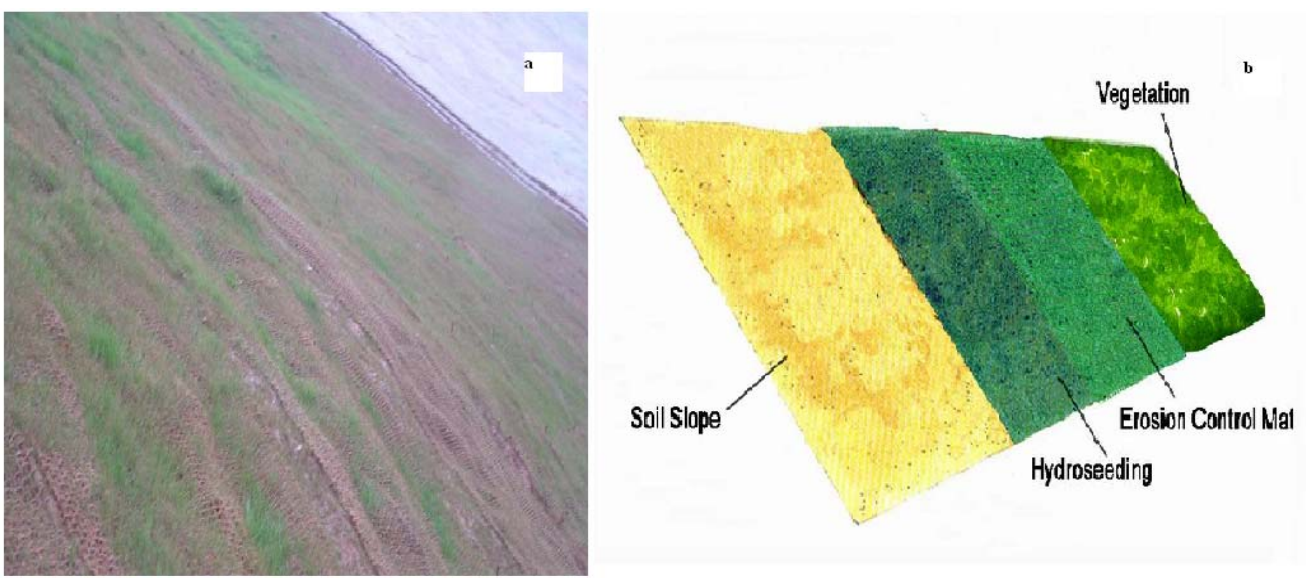


Figure 3 (a) Coir Matting on dump slope (b) Coir matting process

Paithankar A. G. et al, (2001) described the plantation system in the dump slope. Vegetation in dump slope protects dump failures through root systems and plant cover, which improve soil particle aggregation in a low cohesion situation, preventing the dump failures. The Figure 4 shows the vegetation which stabilizes the dump through the root system. The roots of the fast growing plants and bushes penetrate through the failure zones to the stable and the compact soil beneath. So it holds the moving dump soil mass and prevents the dump failures.

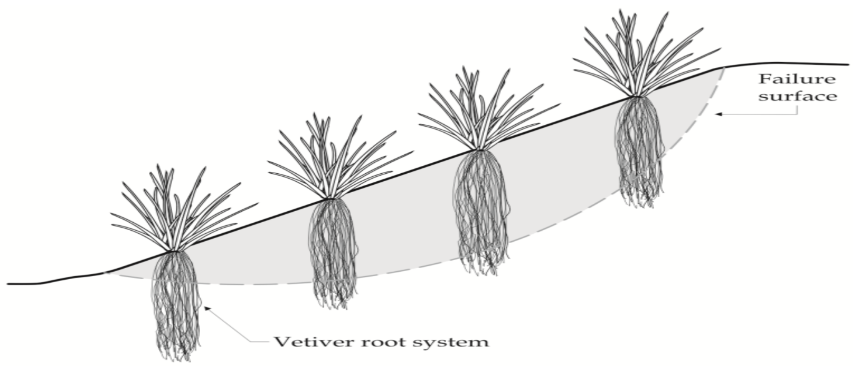


Figure 4 Root System for dump stabilization

# CHAPTER- 3

# Materials and Methods

The overburden samples were collected form various locations form the dump. The samples were packed and brought to the laboratory carefully for subsequent analysis. Various geo-mechanical properties such as grain size, optimum moisture content, dry density, cohesion and internal angle of friction of the dump forming material were determined by following ASTAM-2007. Then these sample properties were used in analysis using the software (FLAC/SLOPE 5.0). The factor of safety was determined for different bench/decks height at various slope angles of the overburden dump.

**3.1 Grain Size Analysis**

Grain size distribution of the overburden dump sample was done by sieve analysis following ASTM D 422. The sieve size used were of 4-75mm, 2.00mm, 1mm, .25mm, .212mm, .150mm, .75mm and pan. The sieve analysis process was carried out by these steps. About 1000 gm of soil was oven dried for 24 hours. The Oven dried dump soil was washed with water on 75 micron sieve. Dump soil retained on sieve was again dried and used in the sieve analysis. The sieve arrangement was done such that coarser sieve was above the finer sieve and the pan below the finest sieve. Entire assembly of sieve was placed on the sieve shaker and was covered properly. The dump soil retained on each of the sieve was weighed.

### 3.2 Standard proctor Compaction test

Compaction test was done to determine the maximum dry density (MDD) and optimum moisture content (OMC) of a given overburden sample using standard proctor method (ASTM D 698). This test determine the optimum amount of water being added with a soil in order to obtain maximum compaction of the dump soil to a degree comparable to that obtained in the laboratory altering the effective lift or number of passes with the available roller. Maximum compaction loads to maximum dry density and hence the deformation and strength characteristics of the soil turnout to be the best possible value.

Standard Procter test apparatus consists of cylindrical mold, collar, base plate, and rammer. The test was carried out by weighing the empty mold ($W_m$).Fix the mold to the base plate at attach the collar to the mold. Applied a thin layer of grease to the inside surface of mold and collar. The dump soil sample was divided into 3 equal parts. Filled the mold with one part of the soil and compact it with 25 evenly distributed blows with the standard rammer. Repeated this process for second and third part of the soil taking precautions to scratch the top of the previously compacted layer with a spatula in order to avoid stratification and achieve homogeneity. Then the mold was detached (with compacted soil on it) from the base plate. After this, the weight of compacted soil along with the mold was noted. This procedure was repeated by taking and adding water 4% more than the previous water content.

### 3.3 Direct Shear Test

Direct shear test was carried out following ASTM D 3080. The test was done to determine the shear parameter of given samples. Shear strength of a dump soil may be defined as the maximum resistance to shear displacement caused by shear. Shear strength in a soil is derived from the surface frictional resistance along the sliding plane interlocking between individual rock grains and cohesion in sliding surface of soil model.

The shear strength of soil is given by Mohr-Coulomb expression:

$S=C+ \sigma_n \tan (ø)$

Where S=Shear Strength
$\sigma_n$ =Normal Strength in failure plane
C =unit cohesion
ø =Angle of internal friction

In a test of soil, there are two basic stages. First nominal load is applied to specimen and then failure is induced by applying a shear stress. If no water is allowed to escape from or enter into specimen either during consolidation is un-drained test. If the specimen is allowed to consolidate under normal load but no drainage of water is allowed during shear, it is called consolidated un-drained or consolidated quick test. The graph is plotted between the shear strength and normal stress. The Test apparatus consists of shear box with its accessories, loading frame, proving ring, dial gauges, sample trimmer, balance, weights, grid plates and spatula. The data taken were: Volume of mold= 97.20 $cm^3$, Weight of soil sample=210.399 gm., Water added= 24.46 ml, Dial gauge constant= 3.3956, Wet density of soil= 2.164 gm. /cc, Optimum Moisture content= 11.639%.

Dump soil sample was prepared containing particles not more than 4.75mmsize. The sample box was transferred into the water jacket placed on the platform of the apparatus with an adjustable loading frame. The ratio was determined and desired normal load was applied with intensity in the range of 0.5 to 2 kg/cm2 though the loading frame, the proving was adjusted such that is attached spindle touches the water jacket outer surface. The dial gauge was attached to the fitting fixed to the vertical and plate. The shear displacement was measured by gauge. The shear displacement was induced at a rate of about 1% strain per minute. The proving ring dial gauge was taken at every reading of shear displacement till failure. The test was repeated on at least two more identified specimens under increased normal loads.

### 3.4 Tri-axial compression Test

Tri-axial test was done to determine the strength parameters of given dump soil sample by unconsolidated un-drained tri-axial test by **(**ASTM Standard D2850**).** The cohesion and frictional angle was obtained by this test. A tri-axial test is intended to provide strength data of a dump soil sample subjected to compressive stresses in three mutually perpendicular directions. The analysis is based on coulomb's envelope for:

$\tau = C + \sigma_n \tan\varphi$ combined with Mohr's Failure Criteria. A Mohr circle with $\sigma_3$ and $\sigma_1$ at failure represents state of specimen at shear. The limitations of predetermined plane of failure, non-uniform stress distribution, inadequate control of drainage and ignoring the effects of minor principal stresses in direct shear stresses can be avoided by using this test. By this test it can be also be possible to measure the pore water pressure and volume change precisely.

Tri-axial Machine consists of lateral pressure assembly and axial load device, Specimen timer with accessories, Specimen mold, Rubber Membrane, Rubber band, Water supply system and air compressor, Balance and oven. Sample was prepared by using the following data. Mold diameter = 5cm, Length = 10cm, L/D Ratio = 2, Volume of the mold=196.25cm$^{3,}$ Maximum dry density= 1.9455gm/cc, Optimum moisture content= 11.02%, Mass of sample required=381.80gm, Water Required= 42.07ml.

About 1000gm of soil sample was dried in oven for 24 hours. The weight equivalent to maximum dry density multiplied by volume of the mold ($W=\gamma_d * \upsilon$) was taken. Then the water equivalent to the optimum moisture content is added in the soil sample. The dump soil sample is properly mixed. The dump soil sample was then put in the mold and properly compacted. The final compaction of soil sample was done by the compaction machine. After that the compacted soil sample was nicely taken out from the mold by unscrewing the knot. Now the sample is ready for the test. Three samples were prepared for the test.

After the sample preparation, it was then tested in the tri-axial testing machine. The sample was put in the rubber membrane using a sheath stretcher with a solid base at the bottom and loading cap on top. The rubber membrane was sealed on both top and bottom with the rubber band. The sample was on the base of the tri-axial cell. The tri-axial cell was then carefully put into position checking that the plunger just rest on the top cap of the sample. The tri-axial cell was properly tightened with the screws. The steel ball was placed in the central groove of the top cap. The tri-axial cell assembly was carefully raised just enough to touch the proving ring of the upper assembly. The tri-axial chamber was filled with water leaving some air space at the top of the cell to facilitate the escape of the air. The required pressure from the compressor cylinder was maintained in the cell. The proving ring and the dial gauge reading were adjusted to zero. The motor was started and recorded the readings.

# CHAPTER: 04

# RESULTS AND DISCUSSIONS

## 4.1 Grain Size Analysis:

Classification of Grain Size is done by their size distribution. Particles having size greater than 4.75mm is called gravel. Particles having size 0.75mm-4.75mm is classified as sand particle. Particles having size 0.75mm-0.002mm is called silt type soil. Below 0.002mm particles are called clay size. Grain size distribution of overburden materials is shown in Figure 5. It is observed that most of the dump samples are of sand size although few samples partly contain silt and gravel.

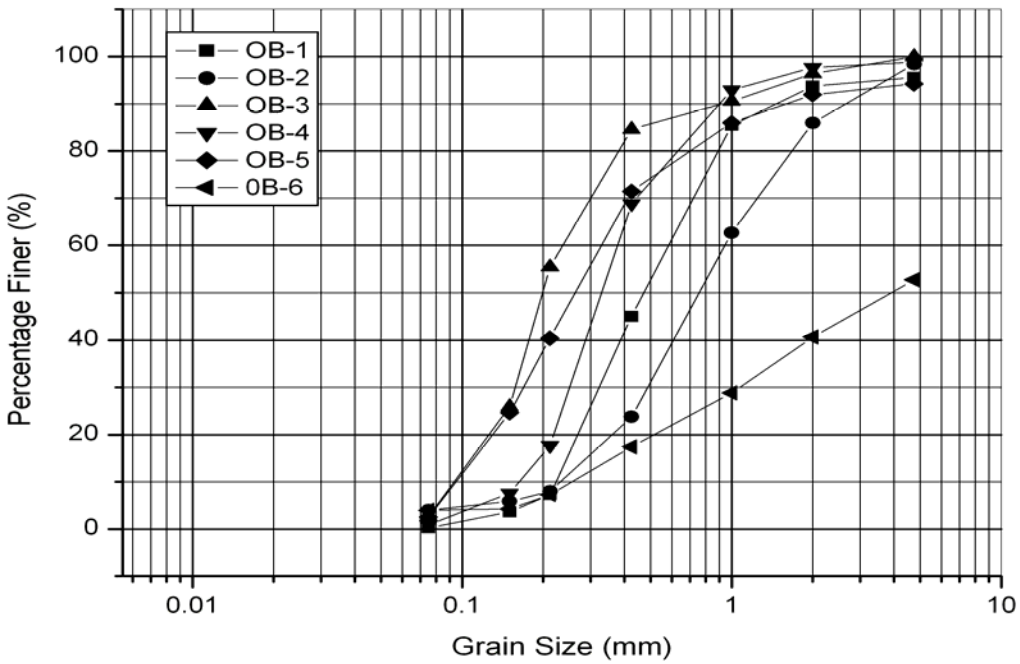


Figure 5. Grain size Distribution in overburden dump

### 4.2 Compaction Study:

The Figure 6 and 7 shows the graphs of dry density vs. moisture content. From this graph we can determine the optimum moisture content and dry density. It is done by the compaction Test/Proctor Hammer Test. This graph explains the maximum compaction of dump soil at optimum moisture content so that the dump is most stable and strong. These parameters are also used in the tri-axial test to determine the weight of sample to be taken and water required to add in the sample.

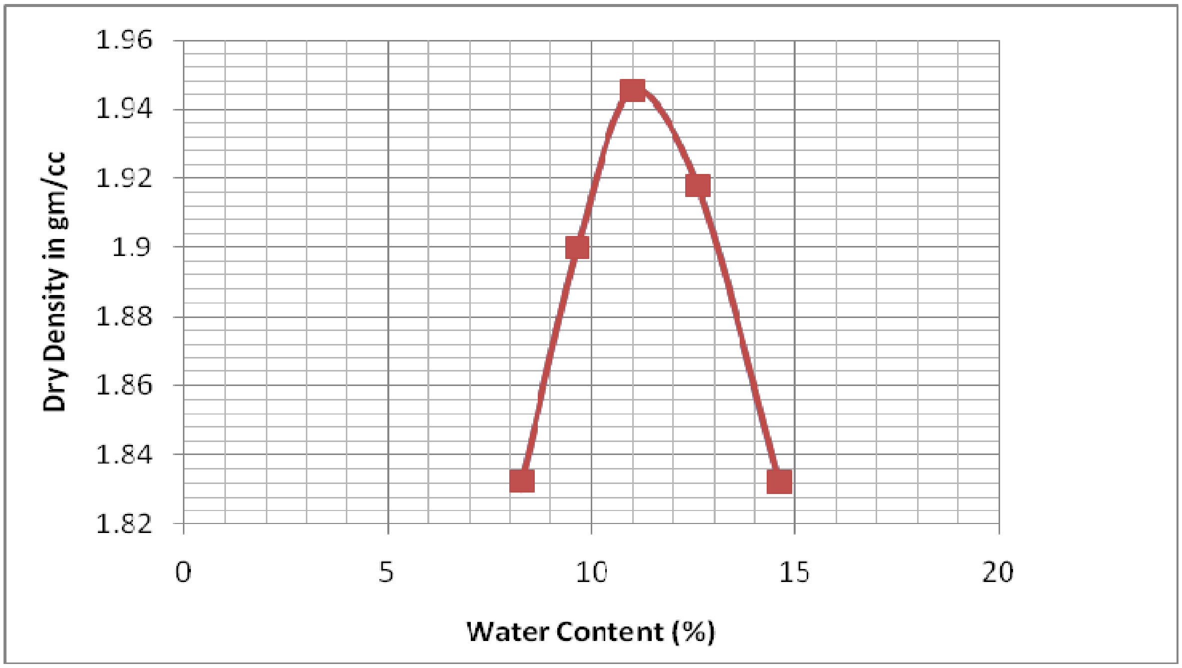


Figure 6. Graph showing the Optimum Moisture Content

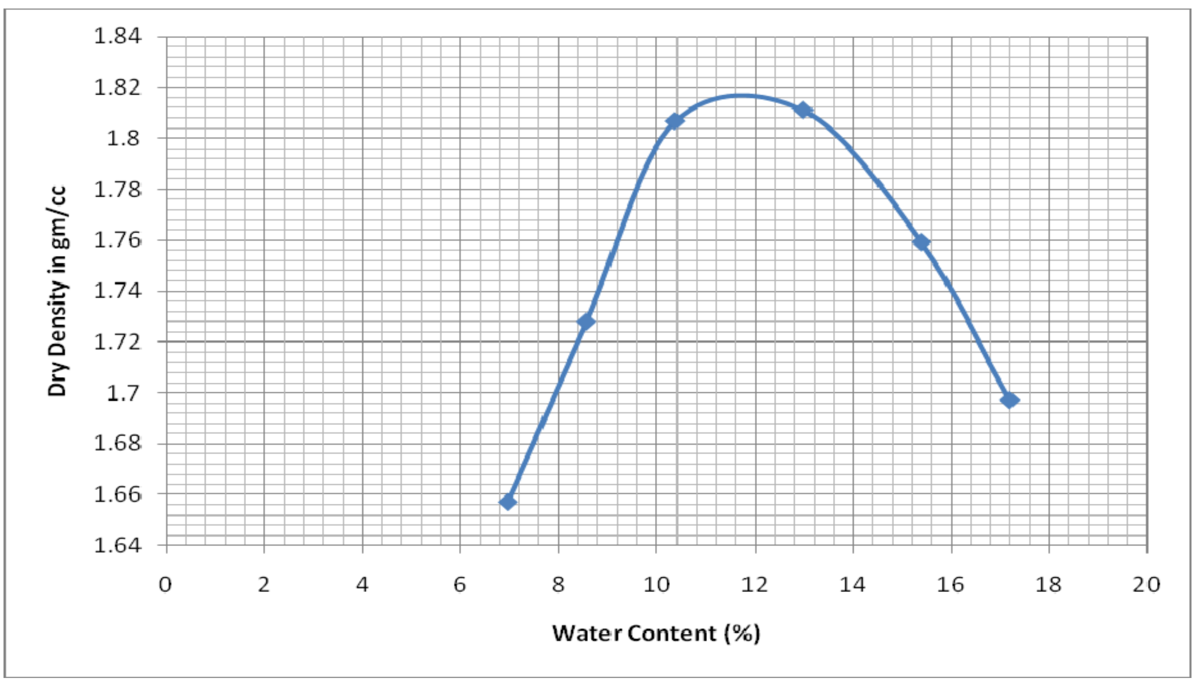


Figure 7. Graph showing the Optimum Moisture Content

Table 3. Dry density and Optimum Moisture content

| Sample No. | Dry Density(in gm/cc) | Optimum Moisture Content (%) |
|---|---|---|
| 1 | 1.945 | 11.02 |
| 2 | 1.938 | 11.63 |
| 3 | 1.810 | 11.50 |
| 4 | 2.025 | 11.5 |
| 5 | 1.791 | 12.20 |
| 6 | 1.318 | 16.10 |

**4.3 Direct Shear Study:**

This test is performed to determine the consolidated-drained shear strength of a sandy to silty soil. The shear strength is one of the most important engineering properties of a soil, because it is required whenever a structure is dependent on the soil's shearing resistance.

From the plot of the shear stress versus the horizontal displacement, the maximum shear stress is obtained for a specific vertical confining stress. After the experiment is run several times for various vertical-confining stresses, a plot of the maximum shear stresses versus the vertical (normal) confining stresses for each of the tests is produced as shown in Figure 8.

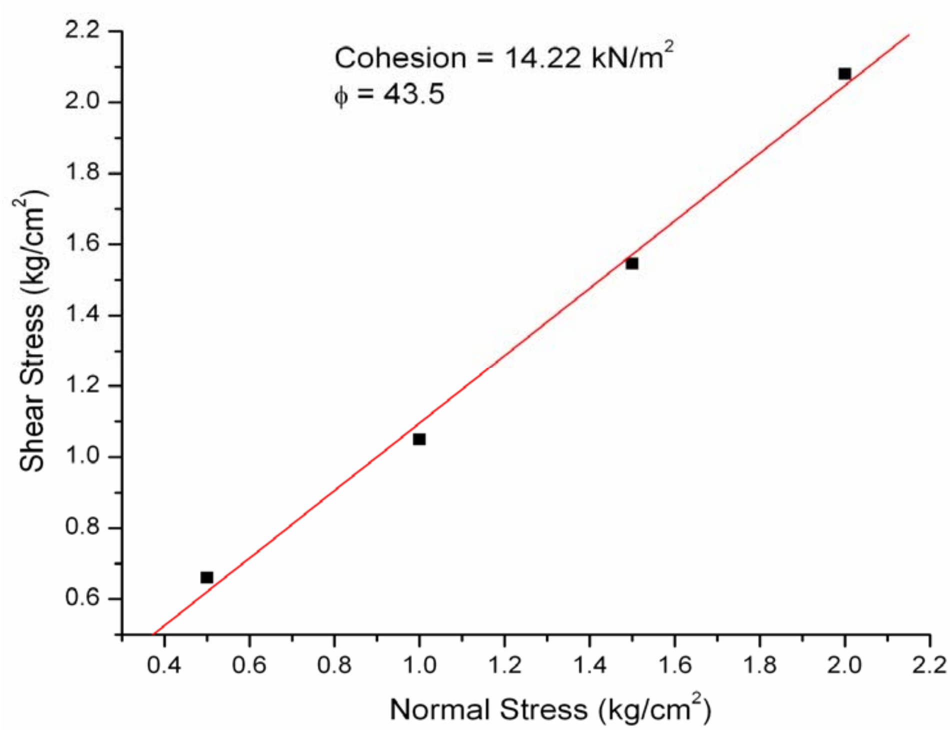


Figure 8 Graph of Shear stress vs Normal stress from Direct shear Test

**4.4 Tri-axial Test Study**

The Triaxial test specimen is subjected to the all round pressure equal to the lateral pressure σ3 and the applied vertical or deviatory stress $\sigma_d$ such that the total vertical stress $\sigma_1 = \sigma_d + \sigma_3$. Mohr stress circles are plotted at normal stress intercepts $\sigma_3$ and $\sigma_1$ .Mohr envelope is then obtained by drawing a tangent to the circles .Then the intercept with Y axis represents the cohesion C and the inclination with X axis represents the angle of internal frictionϕ which is as shown in Figure 9 and Figure 10 .

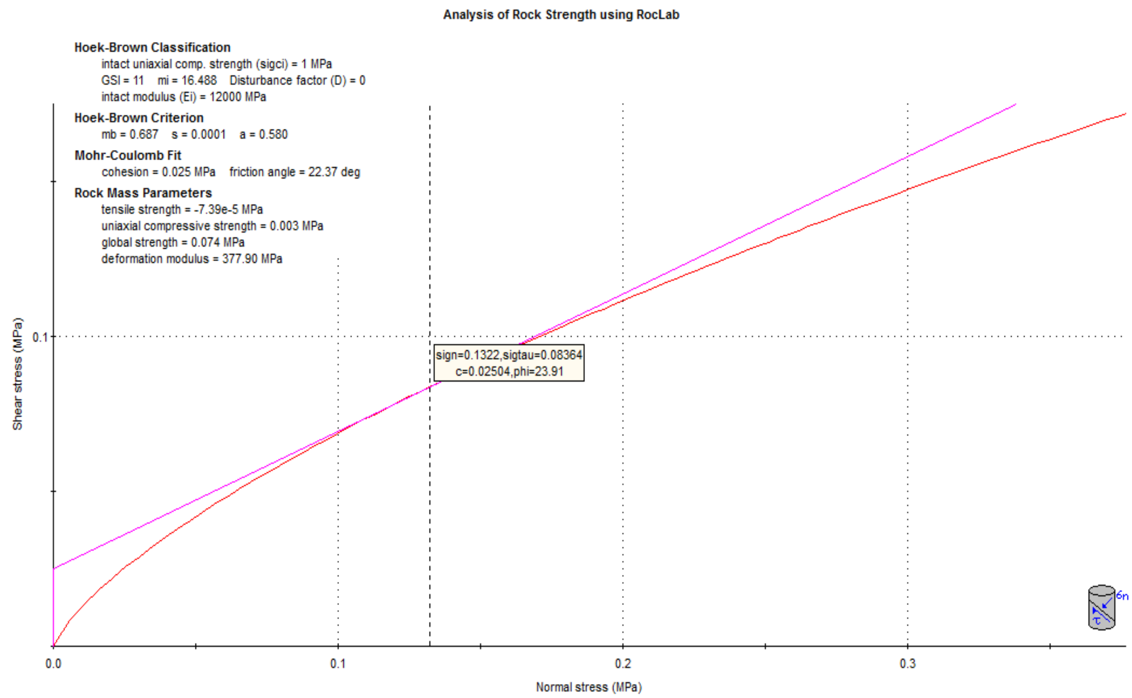


Figure 9 shows C and ϕ value from Mohr Coulomb's Circle from Roc-lab software

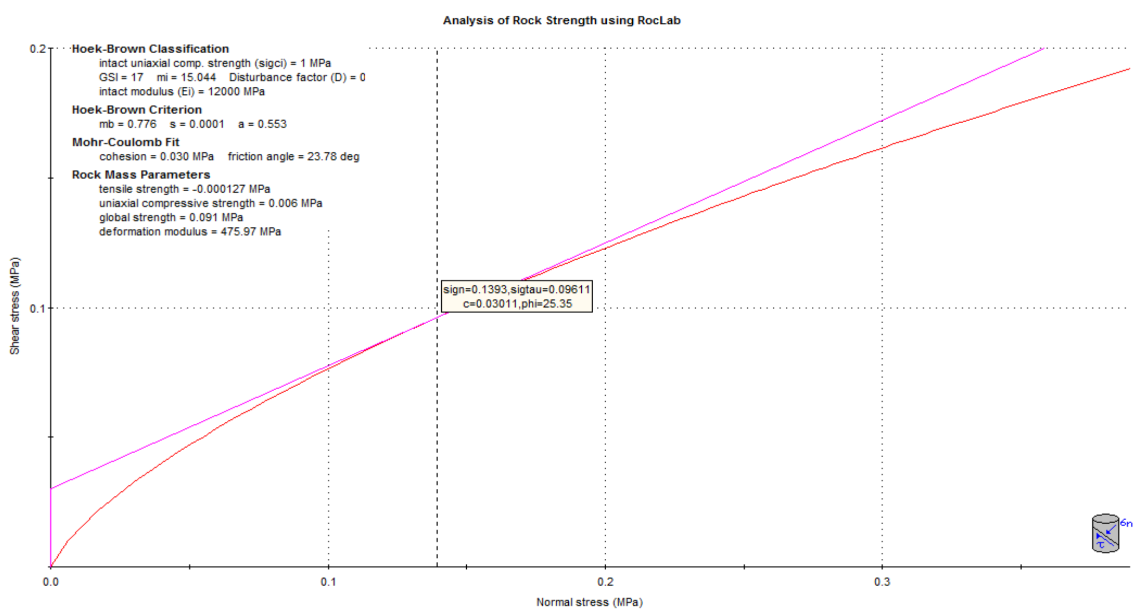

Figure 10 shows C and $\phi$ value from Mohr Coulomb's Circle from Roc-lab software

From this graph we can determine the Cohesion and the frictional Angle of the dump soil samples which are the important parameters in modeling of the dump slope using FLAC slope 5.0. The table 4. contains the cohesion and frictional angle of the four dump soil samples.

Table 4 Cohesion and Frictional Angles

| Sample No. | Cohesion (in Kpa) | Frictional Angle (º) |
|---|---|---|
| 1 | 14 | 13 |
| 3 | 18 | 21 |
| 5 | 25 | 23 |
| 6 | 30 | 25 |

### 4.5 Numerical modeling:

**FLAC/Slope** uses the graphical interface and the automatic factor-of-safety calculation of FLAC as the core of a new, user-friendly code that models slope stability problems under a wide variety of slope conditions. These include: arbitrary slope geometries, multiple layers, pore pressure conditions, heterogeneous soil properties, surface loading, and structural reinforcement.

FLAC/Slope uses the same calculation method as FLAC with a simplified modeling environment that provides tools and facilities exclusive to slope stability analyses. The result is a code that offers rapid model development, proven analytical capabilities, and fast solution reporting. Users of FLAC will find the FLAC/Slope modeling environment familiar.

FLAC/Slope is deliberately designed to perform multiple analyses and parametric studies for dump and rock slope stability projects (Figure 4.9). The structure of the program allows different models in a project to be easily created, stored and accessed for direct comparison of model results. A FLAC/Slope analysis method is divided into four stages. The modeling-stage includes : STAGE-1 Defining Model Stage, STAGE-2 Build Stage, STAGE-3 Solve Stage and STAGE-4 Plot Stage (FLAS/slope 5.0 mannual).

## 4.6 Design of dumps:

The design of overburden dump should be safe and economic in its purpose. The primary aim of the construction of the overburden dump is to provide effective stable working condition in the mines and proper handling of the overburden. The good design of overburden dump prevents accidents and environmental friendly. The dump failures are mainly due to poor construction and design. So the four trials of dump design have been tested for their slope stability. The first three trials are of three decks/benches of 25m, 30m and 35m dump height at slope angles ranging from 25° to 33°. The width of the overburden bench is of 12 m each. The fourth trail is of two decks/benches of height 40 m at various slope angles as shown in the tables below.

Trial-1

In this trial three decks of height 25m and bench width 12m is designed. The change in factor of safety with slope angles is shown in Table 5.

Table 5 Factor of safety with changing slope angle of trial-1

| Slope of each deck | Factor of safety |
|---|---|
| 25 º | 1.47 |
| 27 º | 1.37 |
| 29 º | 1.29 |
| 31 º | 1.24 |
| 32 º | 1.20 |
| 33 º | 1.17 |

From the FLAC SLOPE analysis we determined that the dump with slope angle less than $32^0$ (Figure 11) is the most stable one with safety factor greater than 1.20 and the dump with the slope angle greater than $33^0$ is least stable among others as the factor of safety is below 1.2

(Figure 12). So from the above modeling of trial-1 we choose the dump with slope angle 32° as it is the stable as well as maximum dump capacity.

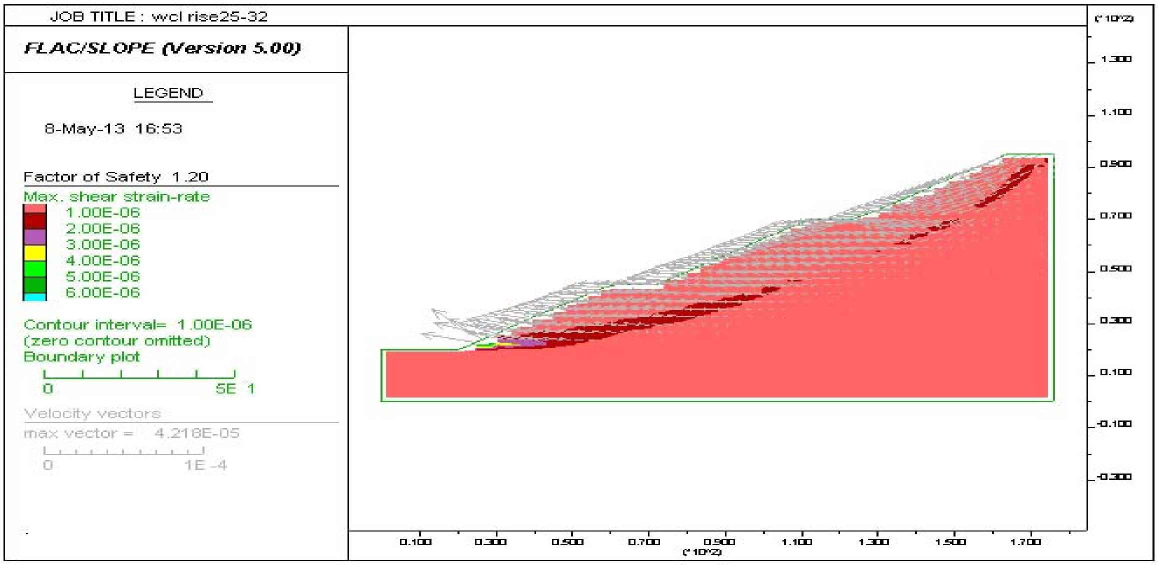


Figure 11 Analysis of the model using FLAC/slope at angle $32^0$

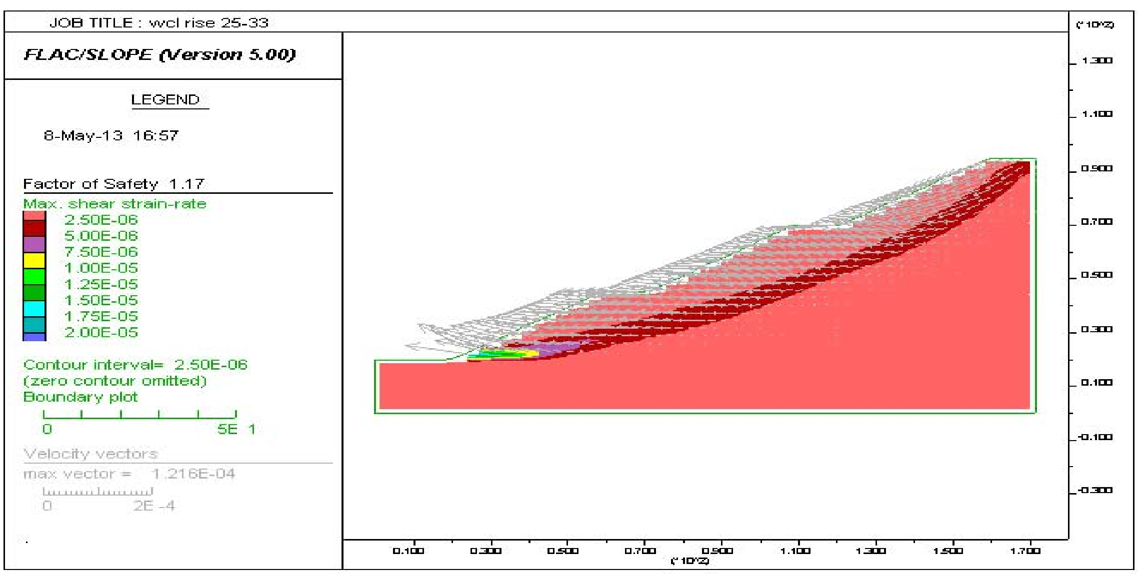

Figure 12 Analysis of the model using FLAC/slope at angle $33^0$

Trial-2

Similarly as in Trial-2 dump was designed with 3 decks and 30m height each .Then the from the analysis we found the factor of safety for angles 25 °,27°,29°,31° which is shown in the table 6.

Table 6 Factor of safety with changing slope angle of trial-2

| Slope of each deck | Factor of safety |
|---|---|
| 25 ° | 1.39 |
| 27 ° | 1.30 |
| 29 ° | 1.20 |
| 31 ° | 1.16 |

From the FLAC SLOPE analysis we determined that the dump with slope angle of $29^0$ (Figure 13) is the most stable one with safety factor 1.20 and the dump with the slope angle $31^0$ (Figure 14)is least stable among others as the factor of safety is below 1.2. So from the above modeling of trial-1 we choose the dump with slope angle $29^0$.

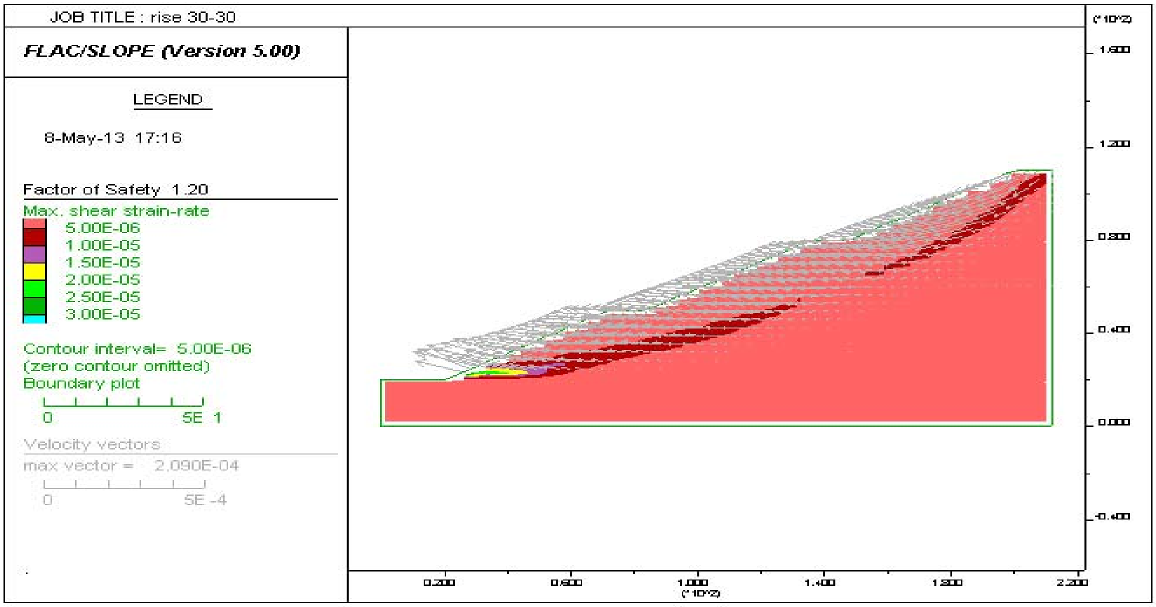


Figure 13 Analysis of the model using FLAC/slope at angle $29^0$

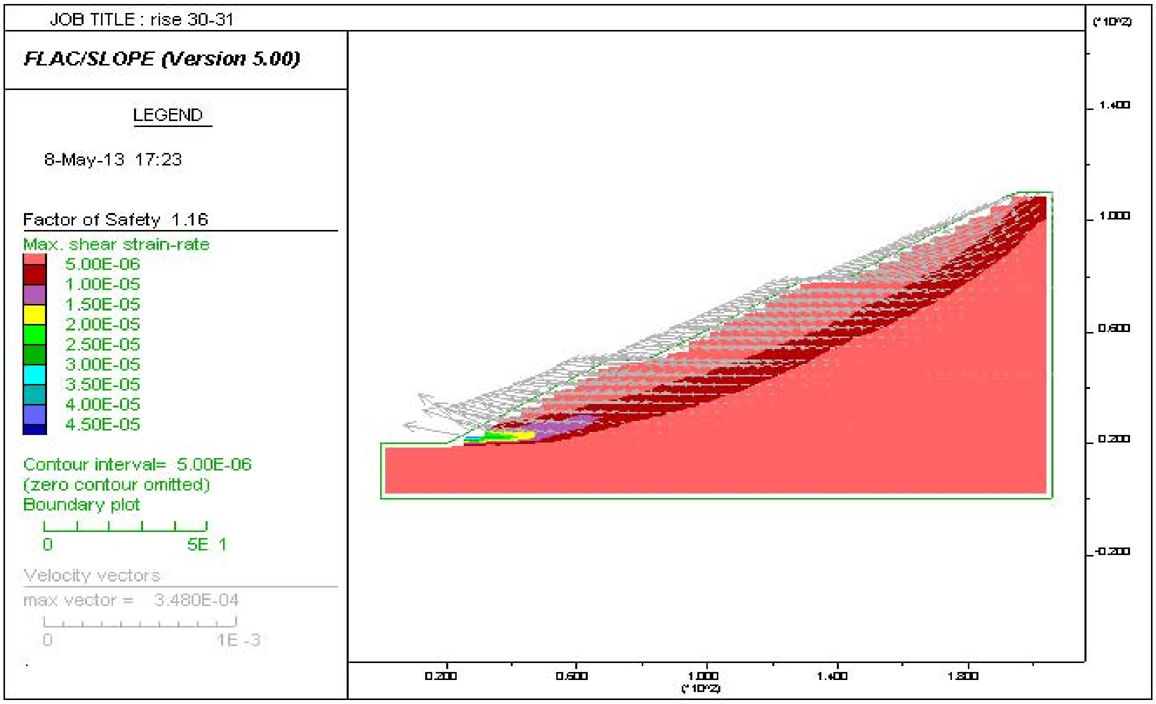


Figure 14 Analysis of the model using FLAC/slope at angle $31^0$

Trial -3

While modeling trial-3 dump height of each deck is taken to be 35m whereas the bench width is taken as 12m.The measured factor of safety of the whole analysis is shown in the Table 7.

Table7. Factor of safety with changing slope angle of trial-3

| Slope of each deck | Factor of safety |
|---|---|
| 25 ° | 1.34 |
| 27 ° | 1.21 |
| 29 ° | 1.18 |

From the modeling analysis we determined that the dump with slope angle of 27° is the most stable one with safety factor 1.21 (Figure 15) and the slope angles less than 27° are also stable. The dumps with the slope angles greater than 29° are not stable.(Figure 16).

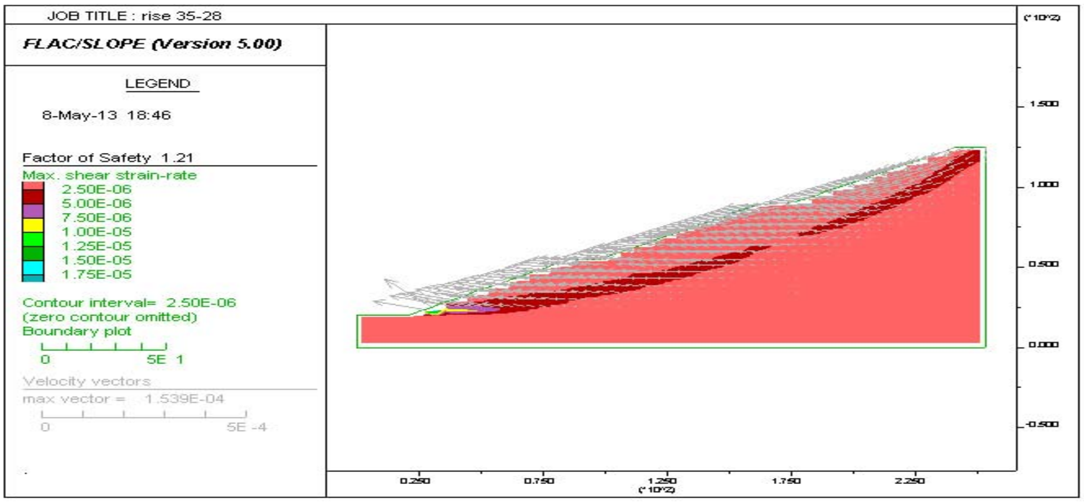


Figure 15 Analysis of the model using FLAC/slope at angle $27^0$

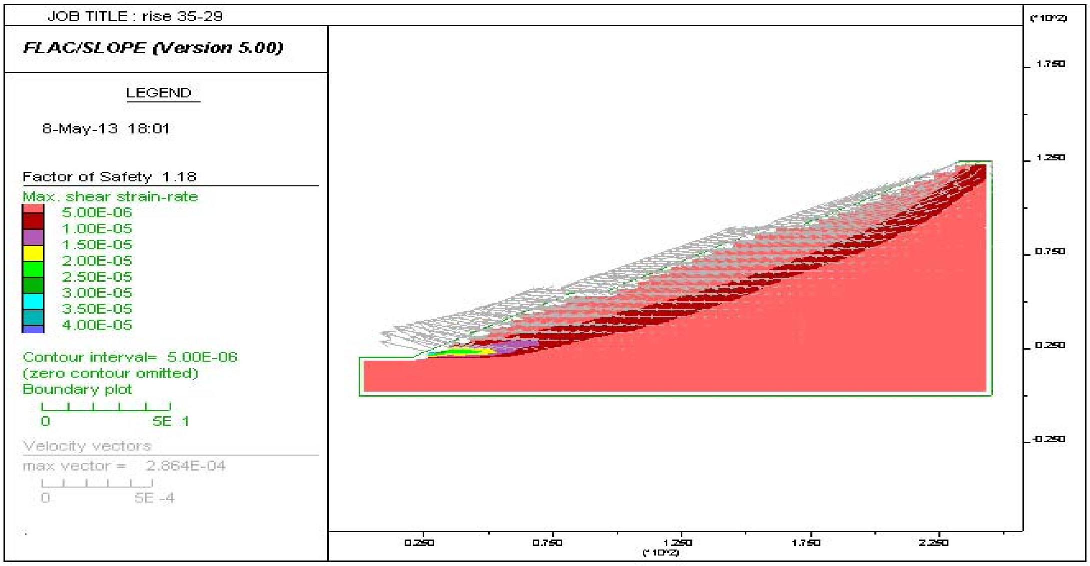


Figure 16 Analysis of the model using FLAC/slope at angle $29^0$

<u>Trial-4</u>

In this trial 40m decks are designed .After modeling the obtained factor of safety is shown in Table 8.

Table 8. Factor of safety with changing slope angle of trial-4

| Slope of each deck | Factor of safety |
|---|---|
| 25 ° | 1.35 |
| 27 ° | 1.26 |
| 28 ° | 1.22 |
| 29 ° | 1.19 |

From the modeling analysis it is concluded that the dumps with slope angle greater than $28^0$(Figure 17) are less stable one with safety factor 1.22 and with slope angles lesser than $28^0$ are considered to be stable. Here the slope angle 29° is not stable (Figure 18)

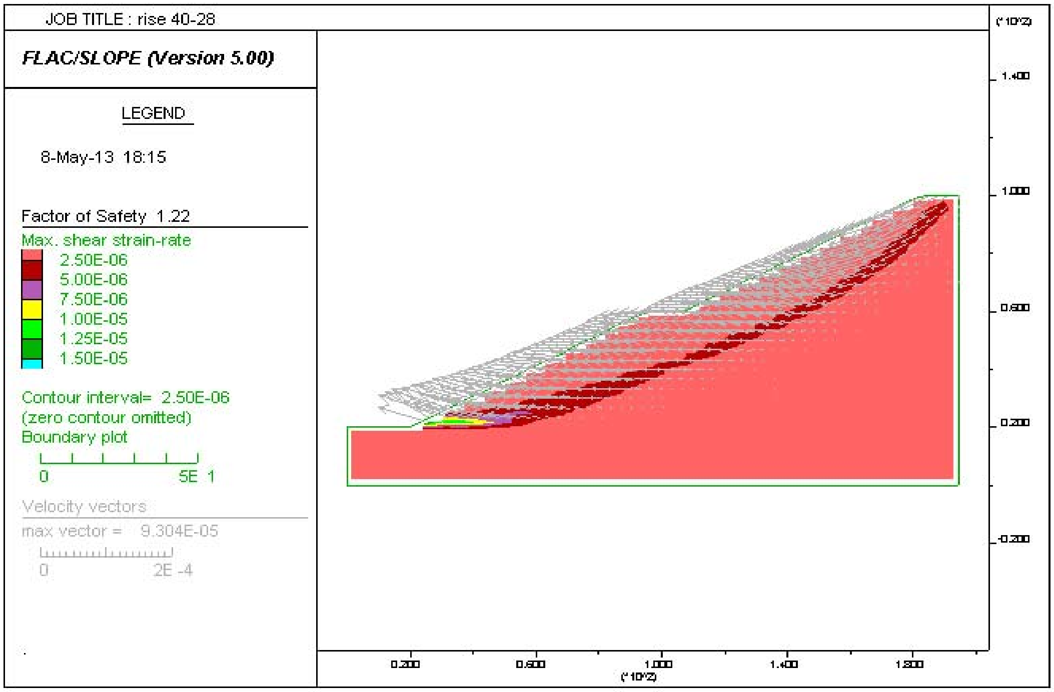


Figure 17 Analysis of the model using FLAC/slope at angle 28°

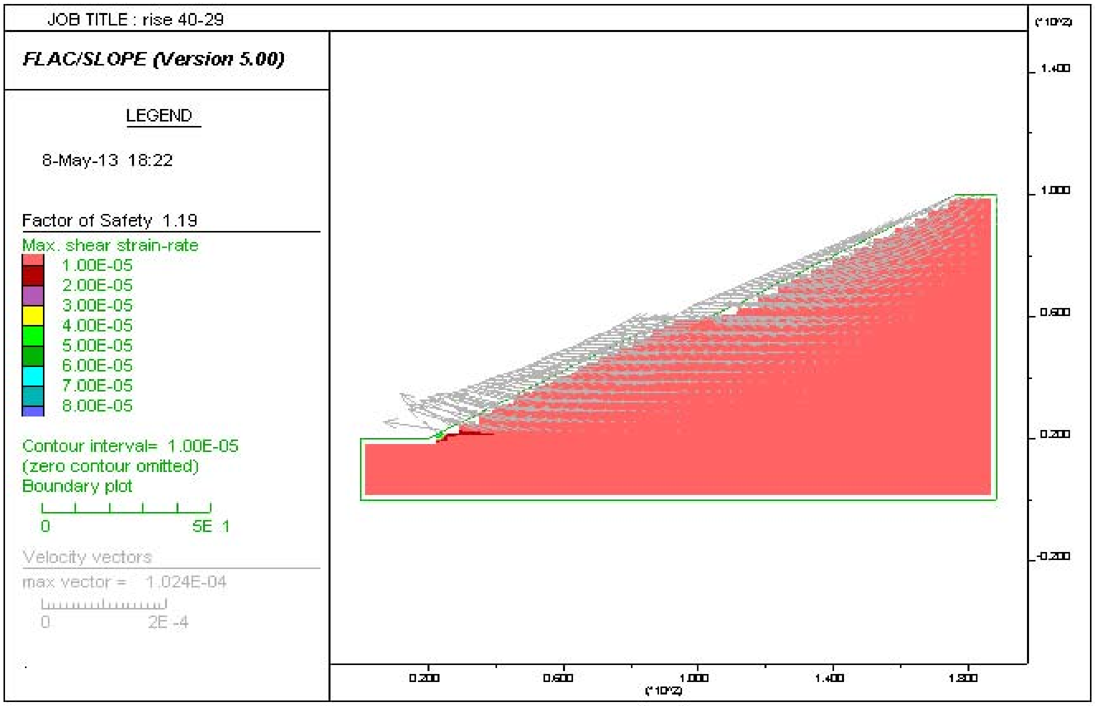


Figure 18 Analysis of the model using FLAC/slope at angle 29°

# CHAPTER- 5

# CONCLUSIONS

From the above study following conclusions can be drawn:

- It has been found out that most of the overburden dump is concentrated by sandy samples as their size ranges from 0.075-4.75mm.
- The dumps were designed in four trials with different slope angles to check the best safety factors.
- The safety factors vary from 1.47 to 1.16 from which we have selected the most stable dump considering both the dump height and safety factor.
- From trial 1 the dump with slope angle of 32° was found to be the stable and dumps with slope angles greater than 32° are not stable. From trial 2 the dumps with slope angles lees than 29° were found to be stable. From trial 3 the dumps with slope angles lees than 27° were found to be stable. . From trial 4 the dumps with slope angles lees than 28° were found to be stable.
- The dump with three decks of height 30 m is at slope angle $29^0$ with safety factor 1.20 is selected as stable and most effective.

# REFERENCE:


1. Abramson Lee. W, Thomas S.Lee, Sharma.Sunil, Boyce Glen M., 2004. Slope Stability and stabilization methods by. A wiley-inter-science publication, 2nd Edition,pp-34
2. ASTM D 3080 - Standard Test Method for Direct Shear Test of Soils Under
3. ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils ASTM International, West Conshohocken, PA, (2007).
4. ASTM Standard D2850,Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils, ASTM International, West Conshohocken, PA, (2007).
5. ASTM Standard D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort, ASTM International, West Conshohocken, PA, (2007).
6. Blanco-Canqui Humberto , Blanco Humberto , Rattan Lal. 2008 . Principles of soil conservation and management.pp-289.
7. Das.S.K. 2008, Surface Mining Technology, 2nd edition, Sagardeep Prakashan, West Bengal.pp.24-26.
8. Datta M, 2006.Geotechnical aspects of landfills and old waste dumps-some case studies, proceeding IGC ,Chennai, India, pp- 221-228
9. FLAC SLOPE Users Guide, 2002.Itasca Consulting Group, Minnesota, pp: 2-5.
10. Hardygóra Monika, Paszkowska Gabriela, Sikora Marek, 2004. Mine Planning and Equipment Selection
11. Jardine R. J., Potts D. M., Higgins K. G, 2004. Advances in geotechnical engineering the Skempton conference) Volume-2, pp-981-990
12. Katti Anand Ramanath, 2002. Behaviour of saturated expansive soil and control methods.PP 803.

13. Kennedy Barbara A., Kennedy Bruce A., 1990. Society for Mining, Metallurgy, and Exploration (U.S.) SME, pp-448.

14. McCarthy, F David. 2011. Essentials of Soil Mechanics and Foundations, Pearson Prentice Hall publication, pp 657-718,

15. Paithankar A. G., Agarwal R. K., Jha Pramod Kumar**,** 2001. Geo environmental Reclamation.pp-16.

16. Qiang He, Shui-Long, 2010. Geo-environmental Engineering and Geo-technics Shen ASCE Publications, pp15-20

17. Sandro Francisco, Holanda Rodrigues and Rocha Igor. Pinheiro da. Streambank Soil Bioengineering Approach to Erosion Control

18. Terzaghi Karl, 1996. Soil Mechanics in Engineering Practice , John Wiley & Sons publicationpp267-pp277

19. Wyllie DC, Mah CW (2004) Rock slope engineering: civil and mining, Taylor & Francis.