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STABILITY ANALYSIS OF INTERNAL DUMP AND NUMERICAL ANALYSIS APPROACH

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ABSTRACT

In opencast coal mines disposal of overburden and maintaining its stability plays vital role. External dumping of overburden requires additional land and its stability is a major issue and poses environmental problems in the surrounding areas. This has led to preference of internal dumping in which the overburden waste rock is dumped in de-coaled area which is beneficial during extraction and reclamation of the mine. Internal dumping is more economical and environmental friendly method of waste disposal and is being practiced in most of the opencast coal mines. Internal dumping has certain inherent limitations such as proneness of failure of slope posing operational and safety threats. In this paper a numerical analysis of stability of internal dump of 100 m height of SRP Opencast mine of SCCL, Telangana, India is done. In the present case study, the internal dump is located over de-coaled area with number of fault planes. Stability analysis of internal dump is carried out by simulating various situations with and without presence of fault planes using UDEC 6.0, Rocscience 9.0 (FEM) and results are compared.

Keyword Internal dump stability, Opencast coal mining, Overburden disposal, Slope failure analysis

1. INTRODUCTION

In present days, the demand for coal has increased for industries as well as in domestic purpose. Recent years has witnessed drastic increase of production of coal to cater the needs of power plants as specified by M/s Singareni collieries company limited (SCCL) report [1]. The targeted production of SCCL during 2016-17, 2017-18 is 61.34 Mt, 66.06 Mt and majority of the targeted production comes from opencast mines. With the increasing size of opencast mines and the large stripping ratio associated with these mines, the amount of overburden removal increased substantially.

The overburden dumps can be external dumps created at a site away from the coal bearing area or it can be internal dumps concurrent to the creation of voids by extraction of coal. Practice of external dumps have some serious problems (Upadhyay.et.al) [2] foremost among them are requirement of additional land, involves very high transport and re-handling cost which will increase the cost of coal production, stability and reclamation of the site. The use of excavated area as dumping site can overcome above problems to a great extent. The option of external dumps cannot be eliminated even if we adopt internal dump practice. However, the combination of external dumps and internal dumps shall substantially reduce the land requirement. As a result, it shall reduce the surface land requirement significantly which is very difficult task to arrange in any area due to growth of population forest cover and other associated problems (Dhananjay Verma.et.al) [4].

Stability of overburden dump is essential for smooth mining operations; hence proper management of dump is required in the mining lease area to avoid any slope failure (Dhananjay Verma.et.al) [3]. There are a number of cases where dump failure has been encountered in India which has caused significant damage to mining properties, loss of lives and interruption in production (Tripathi.N.et.al) [6]. Some of the dump failures have occurred in Singareni collieries during December 2009 (Radhakanta Koner.et.al) [7]. Therefore, it becomes necessary to conduct analysis of existing dumps. Consequently, a proper design of internal dump should be carried out to ensure the safety of working persons and machinery.

There are a number of factors, which effects the stability of dump [6] (Griffiths.et.al) [8]. These factors are broadly classified as

- Geometry and strength of the dump material
- Load bearing capacity of dumping area
- Hydro-geological and rain water conditions of dumping site
- External loading conditions and dynamic forces

The slope geometry and geo-mechanical strength of the dump material always control the stability of the dump [2] (Upadhyay.et.al) [9] (Singh, T. N. et.al) [10]. Dump material is anisotropic in their behavior and its stress - strain behavior is quite erratic, owing to presence of clay mineral. The visco-elastic behavior due to presence of water poses serious threat during rainy season. The shear strength reduction due to raise in pore water pressure leads to failure. Consolidation and compaction is another key factor because of the uneven size distribution of the dump material.

Bearing capacity of the ground has a direct influence on the stability of the dump slope. A sloping ground with low bearing capacity lead destabilizing of the dump slope stability due to foundation failure (Singh, T. N. et.al) [11]. Dynamic forces such as blasting and earthquake liquefy the dump material, reducing its shear strength.

In this paper, numerical analysis of stability of internal dump slope (Figure 2) has been carried out using UDEC 6.0 limit equilibrium method and FEM with Strength Reduction approach.

Figure 1. View of SRP Opencast mine

2. Geology of the Area

The SRP OCP-1 mine is situated in the southern part of Somagudem, Indaram coal belt in Adilabad District of Telangana with a targeted out of 2.5 mt per year. The mine is located in the southern part of Somagudem – Indaram coal belt between north latitude 18° 51′12″ and east longitude 70° 31′ 18″. The mine is planned to be worked with shovel dumper combination with a stripping ratio of 8.46 m^3 / tonne to a depth of 230 m and total over burden removal is expected to be 475.8 million cubic meters during 23 years of mining operations. The coal seams are associated with number of fault planes A-A1, F-F1 with an up throw varying from 2 m to 10 m. During the process of coal mining overlying strata consisting of topsoil and sedimentary rock formation shall be removed as overburden during different stages of mining. The view of SRP opencast mine is shown in figure 1.

The overburden dumps are maintained as external dump as well as internal dumps. The external dump is surrounded by small villages which are susceptible to the danger of dump failure. Hence analysis of dump stability is very important to ensure the safety of persons residing in the surrounding villages. The external dump is being maintained in number of benches of each 30 m height and 30 m width up to 4 benches with maximum over all height of 120 m. The angle of inclination of each bench is 37.5^0, with over all dump angle of 34^0.

The internal dump of SRP opencast mine is located in the de-coaled area of 3 Seam (Figure 2). At the floor of the dump number of faults are there. Internal dump is constructed in 3 benches each bench is having bench height of 30 m, width 30m with a bench slope angle of 37.5^0. The overall height of internal dump is 90 m.

Figure 2. Internal dump placed over 3 Seam de-coaled area

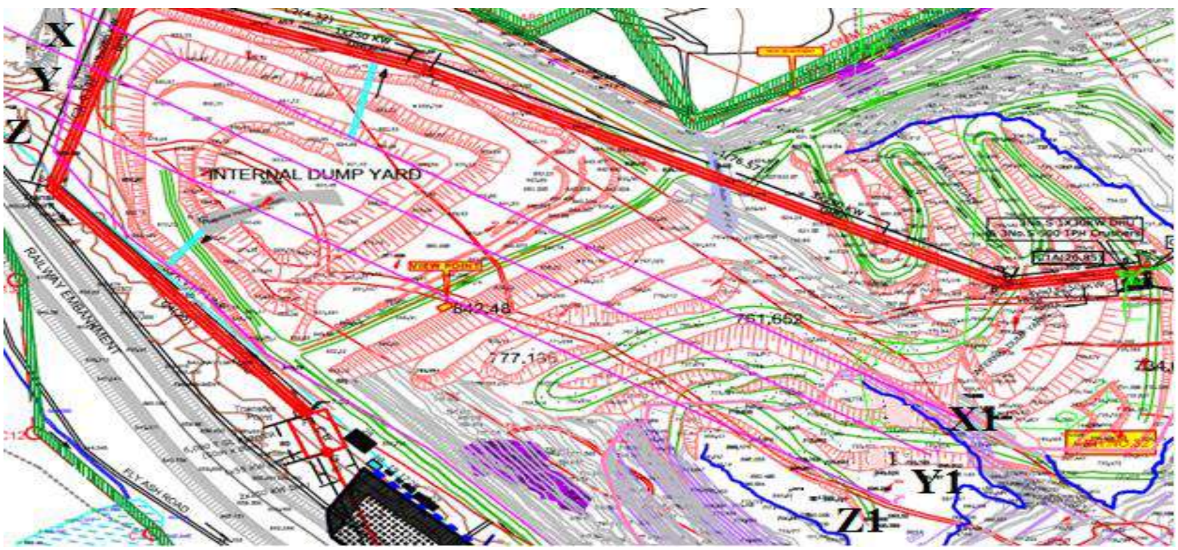


Figure 3. Plan of internal dump

3. Stability features of internal dump

In case of Internal dump meticulous planning of dump parameters such as height, width and slope angle of the bench is required to prevent failure of dumps. Unplanned dumping can be threat to life and property (Dhananjay Verma.et.al) [4][5]. The internal dumps are affected by the particle size of waste material, geometry, unit weight, shear strength, pore pressure and foundation of the dump material (Upadhyay.et.al) [2](Dhananjay.Verma.et.al)[3][4].

For the present study detailed systematic sampling was carried out for sections X-X1, Y-Y1 of the dump at various locations. The dump material was tested in the laboratory for the assessment of their strength properties as per standards. The samples were tested in dry as well as saturated condition when pores were fully charged with water. The dump material mainly consists of sandstone, shale and carbonaceous shale.

Table 1: *Properties of fault plane in coal fields of Godavari basin of SCCL [5]*

S. No	Type	Normal stiffness (Gpa /m)	Shear stiffness (Gpa /m)	Friction angle
1	Fault	0.8	0.05	30

Table 2: *Physico mechanical properties of dump*

S. No	Type of material	Unit Weight (KN/m^3)	Youngs Modulus (Gpa)	Poisson's ratio	Cohesion (KPa)	Internal friction (^{0})
1	VFG SST to Shaly	22.955	7.3575	0.31	53.955	32
2	Fine to Medium Grain Huge Quartz Boulders	25.702	6.4746	0.33	45.616	30
3	Very fine to Medium grain Sandstone with pebbles at the bottom	23.544	7.5537	0.326	53.855	35
4	Shale with Quartzite huge Boulders	25.898	5.0031	0.32	37.278	32
Average		25.898	5.0031	0.32	37.278	32

The internal dump is constructed over 3 Seam de-coaled area, which is of sand stone whose properties are given below

Table 3. *Physico mechanical properties of foundation material (Sandstone)*

S. No	Type of material	Unit weight (KN/m3)	Youngs Modulus (Gpa)	Poisson's ratio	Cohesion (Kpa)	Angle of internal friction (0)
1	Sand Stone (Foundation material)	21.68	4.462	0.26	36.2846	40

4. Numerical Analysis of Internal dump by RS2 9.0 (FEM) and UDEC 6.0 (FDM)

In the present case Internal dump is constructed over a de-coaled 3-Seam area which has number of fault planes at the floor. Numerical analysis for stability analysis is being carried out by Rocscience Phase2 9.0 (Finite Element Method) using strength reduction factor method and UDEC 6.0 (Finite Difference Method) limit equilibrium method.

Finite Element Method (FEM) method is most commonly used method of computation of stability of dump slope. One of the popular method of determination of FEM stability analysis is Shear Strength Reduction (SSR) method (Griffiths. D. V. et.al) [9]. The SSR technique for slope stability analysis involves systematic use of finite element analysis to determine a stress reduction factor (SRF) or factor of safety value that brings a slope to the verge of failure. The shear strength of all the materials in a FEM model of a slope are reduced by the SRF (Singh. T. N. et.al) [10]. Dump FEM analysis is then performed until a critical SRF value that indicates instability is attained. A slope is considered unstable when its FEM model does not converge to a solution (with in specified tolerance). In this method Mohr-Coulomb constitutive model has been used to describe the material properties (Singh, T. N.

et.al) [11]. The criterion of Mohr-Coulomb model relates to the shear strength of the material to cohesion, normal stress and angle of internal friction.

UDEC 6.0 (Universal Distinct Element Code) is a two-dimensional numerical modeling software which simulates the quasi-static or dynamic response to loading of media containing multiple, intersecting joint structures. The discontinuous medium is represented as an assembly of discrete blocks while the discontinuities are treated as boundary conditions between blocks. Large displacements along discontinuities and rotations of blocks can occur. UDEC utilizes an explicit solution scheme that can model complex, non-linear behavior. Models used for the analysis using UDEC may contain a mix of rigid and deformable blocks. Deformable blocks are defined by continuum mesh of finite difference zones (FDM) (ItascaInc.UDEC 6.0) [24]. The stability analysis of complex slope geometry which contains number of discontinuities is analyzed by Limit Equilibrium method.

4.1 Internal dump – Section X-X1 numerical modeling by UDEC6.0 and RS2 9.0

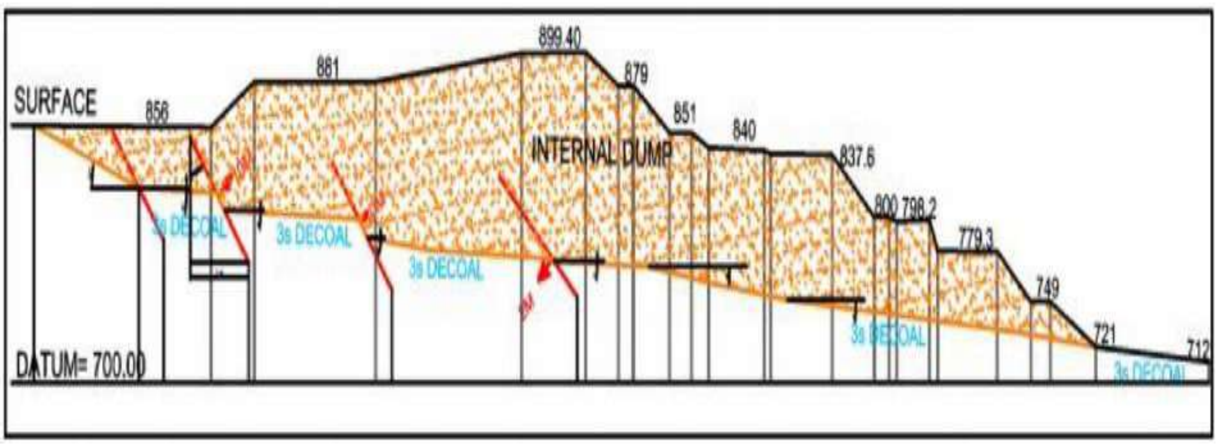


Figure 4: Plan of Internal dump – Section X-X1

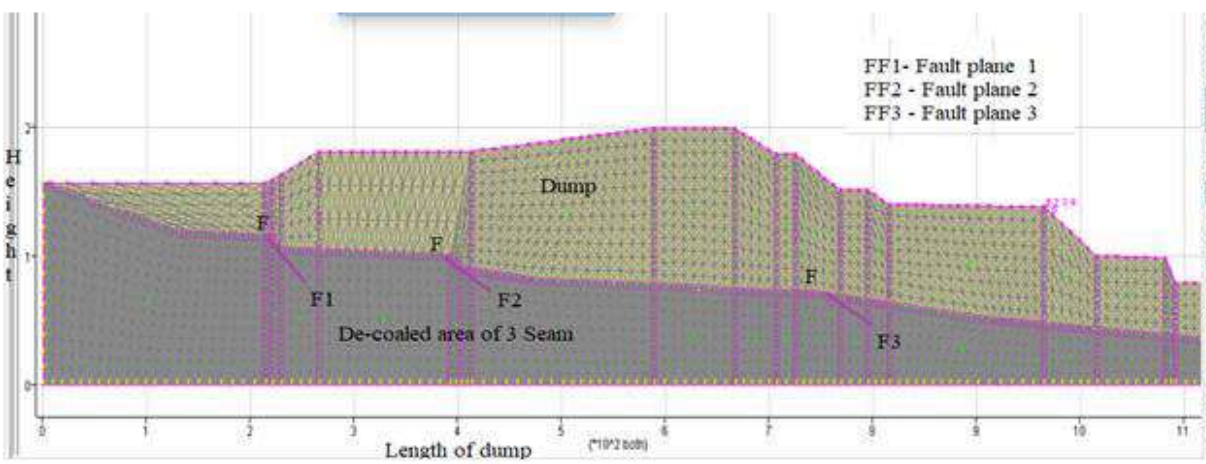


Figure 5: Internal dump Section X-X1 – numerical model by UDEC 6.0

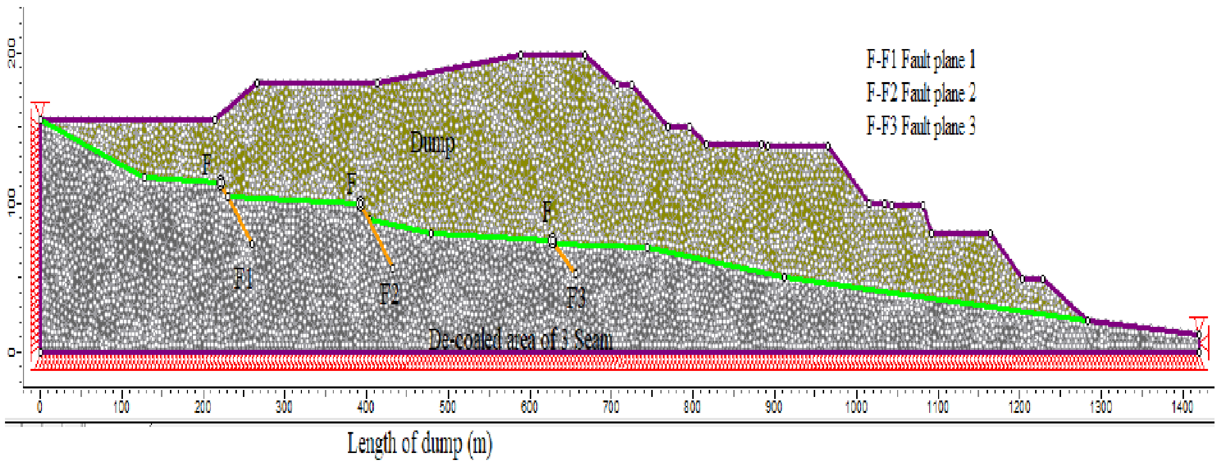


Figure 6 Internal dump Section X-X1 – numerical model by RS2 9.0

4.2 Internal dump – Section Y-Y1 numerical modeling by UDEC6.0 and RS2 9.0

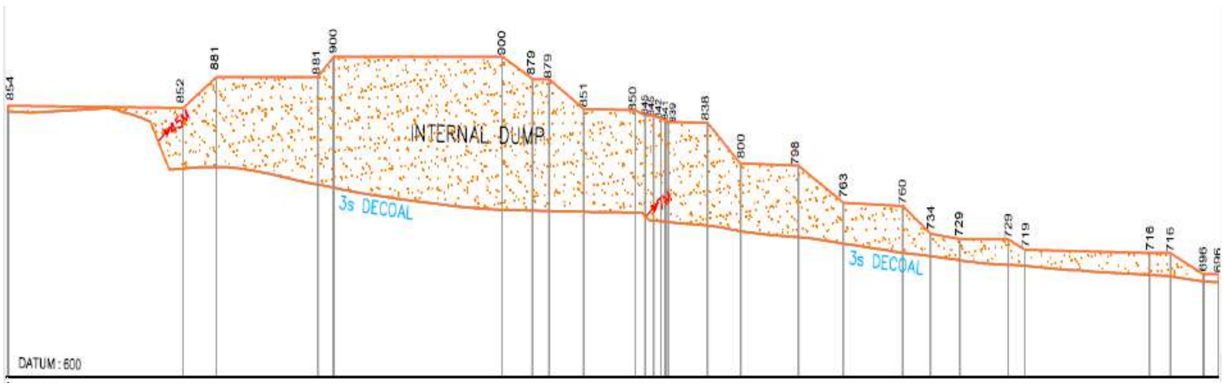


Figure 7 Plan of internal dump – Section Y-Y1

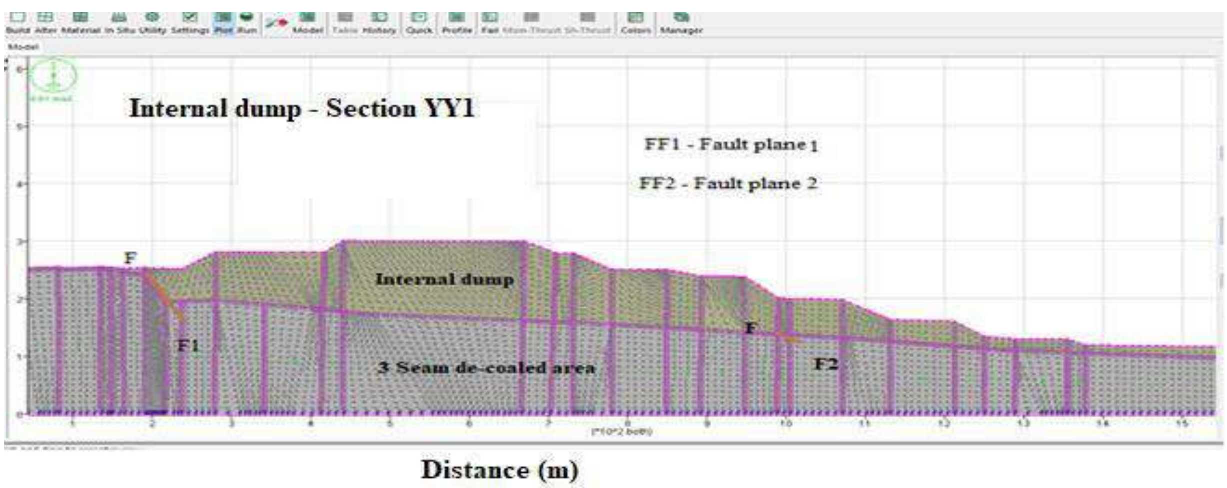


Figure 8 Internal dump – Section Y-Y1 Numerical model by UDEC 6.0

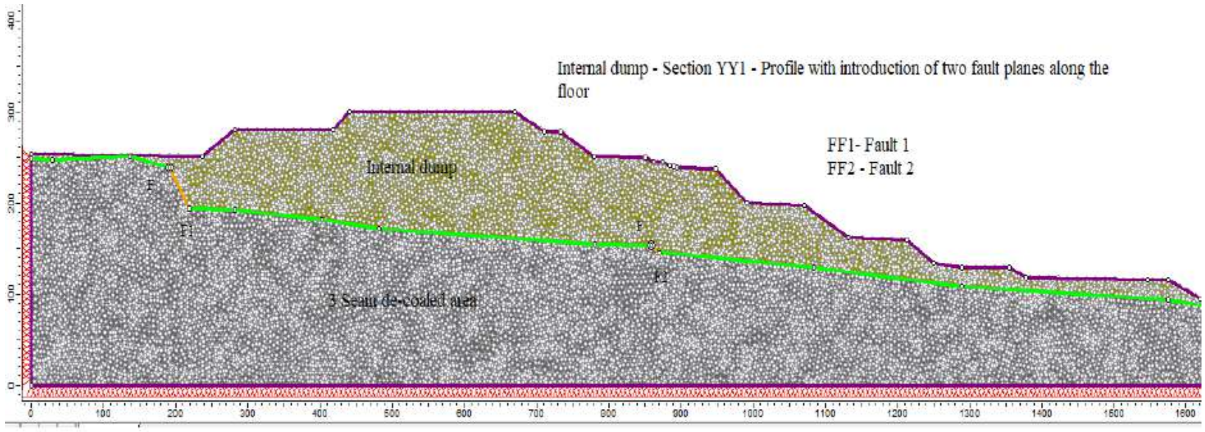


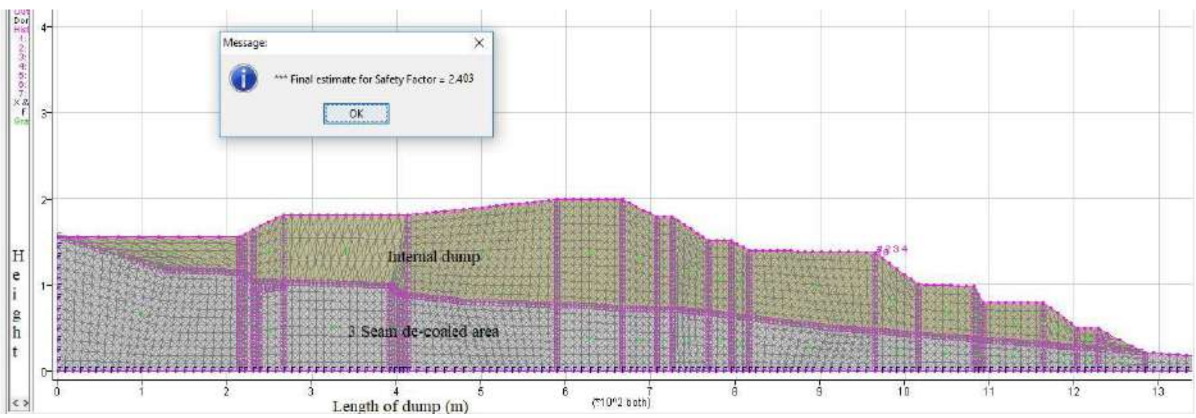
Figure 9 Internal dump – Section Y-Y1 numerical model by RS2 9.0

5.0 Results and Analysis

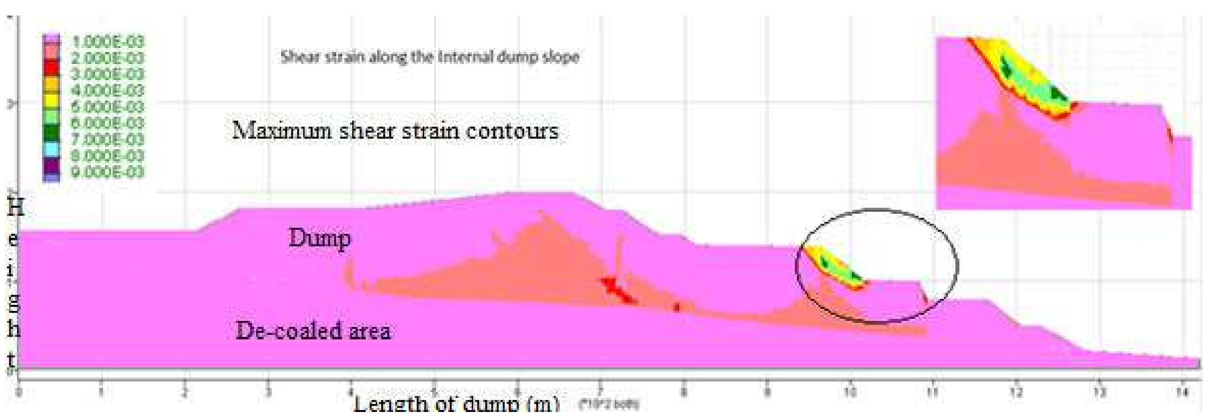
For the computation of stability of slope at various sections of dump using UDEC 6.0 and RS2 9.0 the fault planes along the floor of dump are added sequentially and results are compared

5.1 Internal dump Section X-X1 Stability analysis

Case 1 Using UDEC 6.0 without addition of fault plane along floor



(a)



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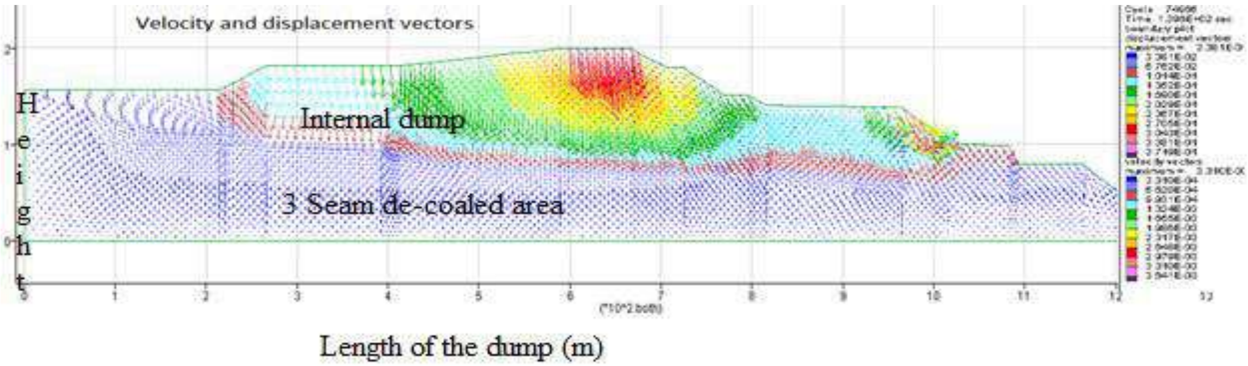


(c)

Figure 10 UDEC Analysis a) Computation of FOS b) Shear strain contours c) Velocity and displacement vectors

Case 2: FEM Analysis with and without fault planes along base of internal dump

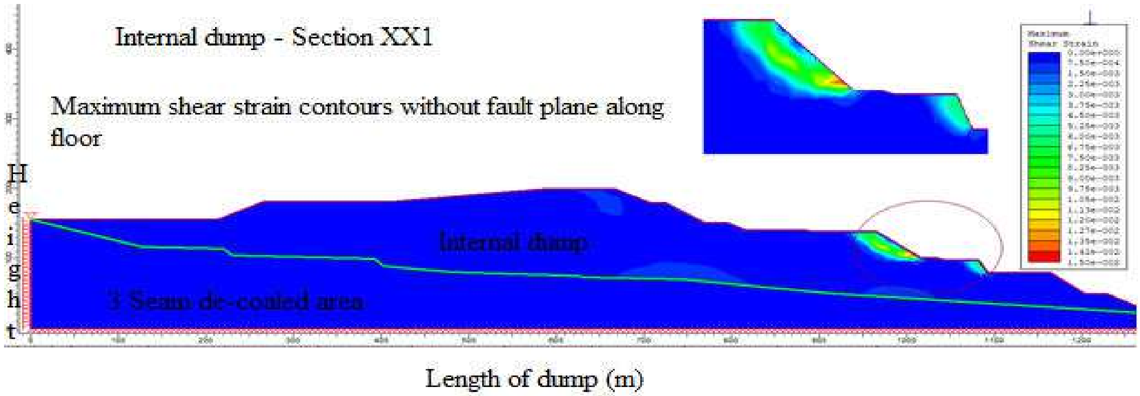
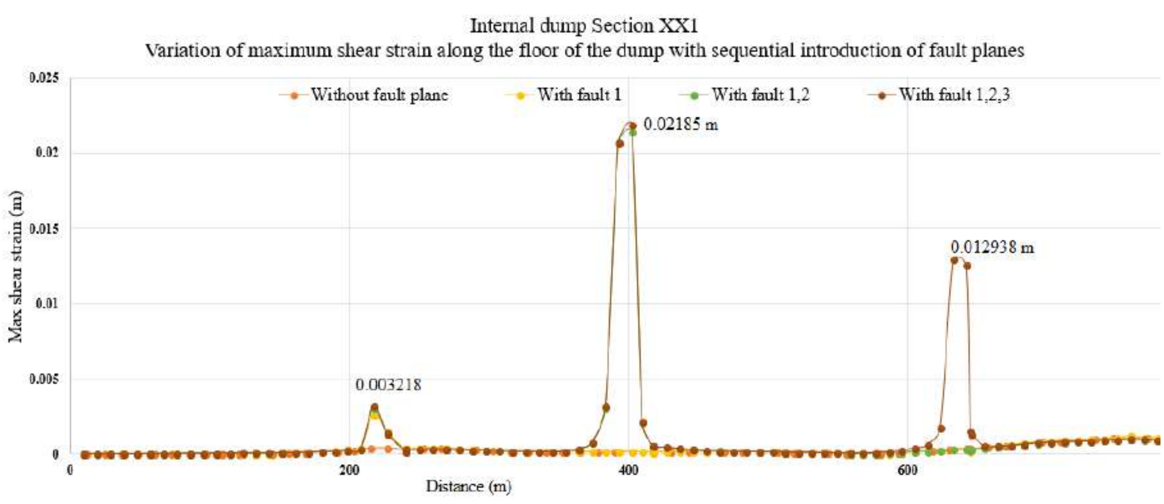


Figure 11 Maximum shear strain contours using FEM analysis

Case 3: Using RS2 9.0 (FEM) Analysis – Graphs showing variation of maximum shear strain, total displacement along the floor and profile of the dump with sequential introduction of fault planes.



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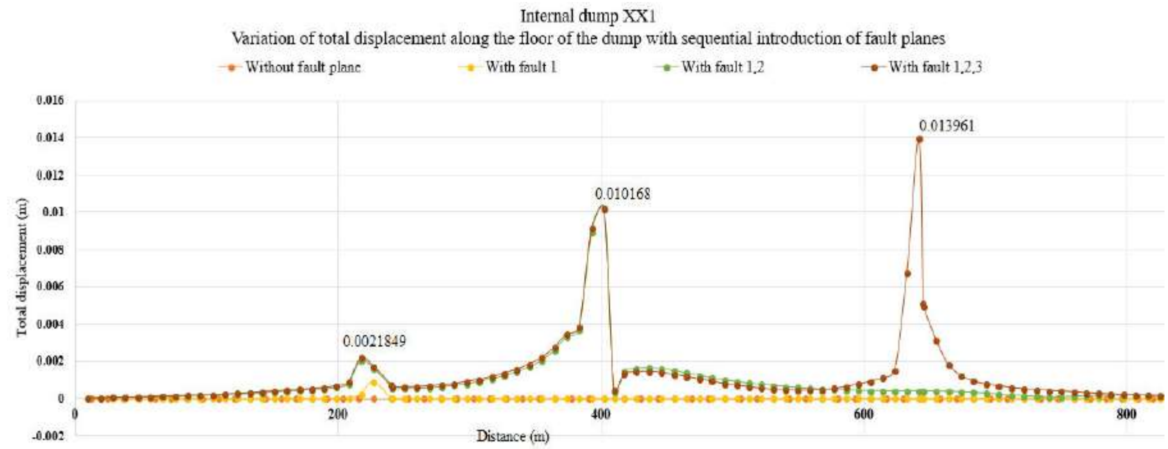

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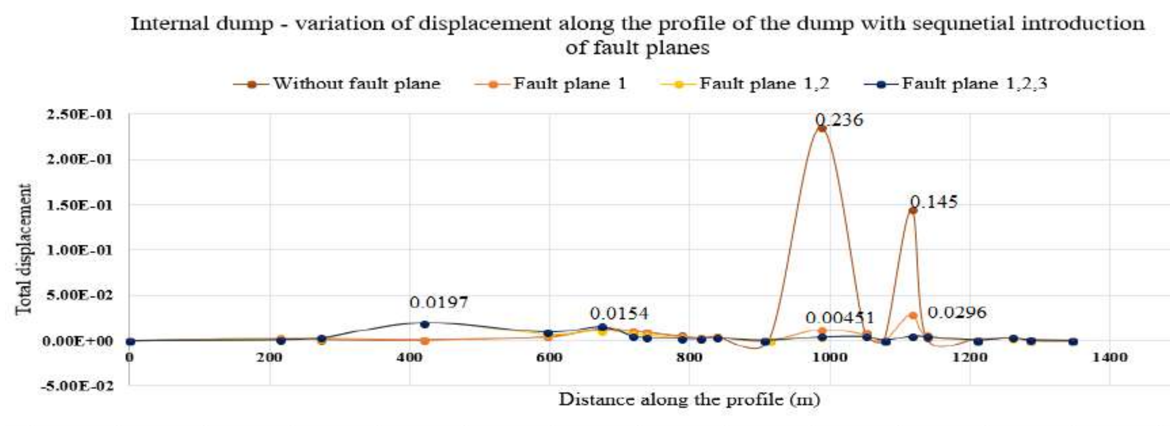

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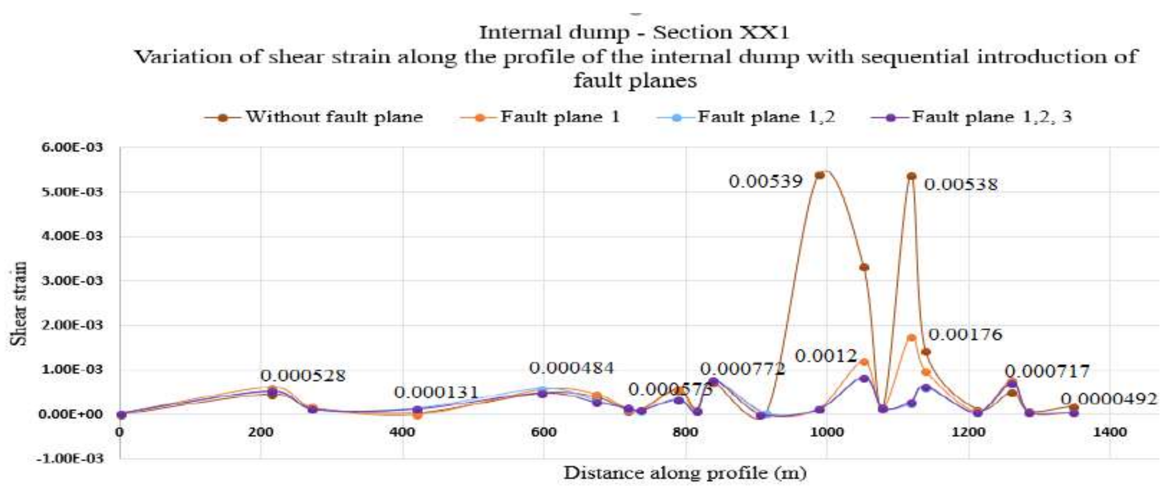
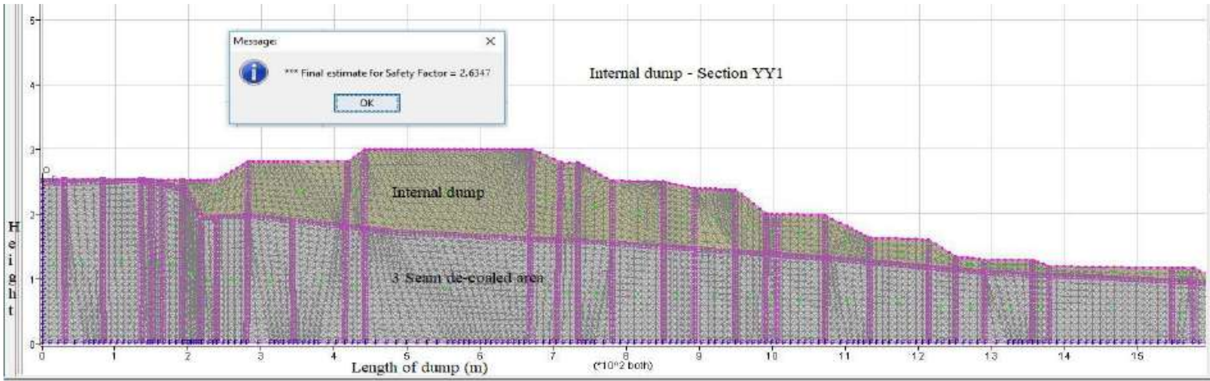


(d)

Figure 12 RS2 9.0 (FEM) Analysis a) Max shear strain along floor of dump b) Variation of total displacement along floor of dump c) Total displacement along profile d) Total shear strain along profile

5.2 Internal dump -Section Y-Y1 Stability analysis

Case 1. Using UDEC 6.0 without addition of fault plane along floor



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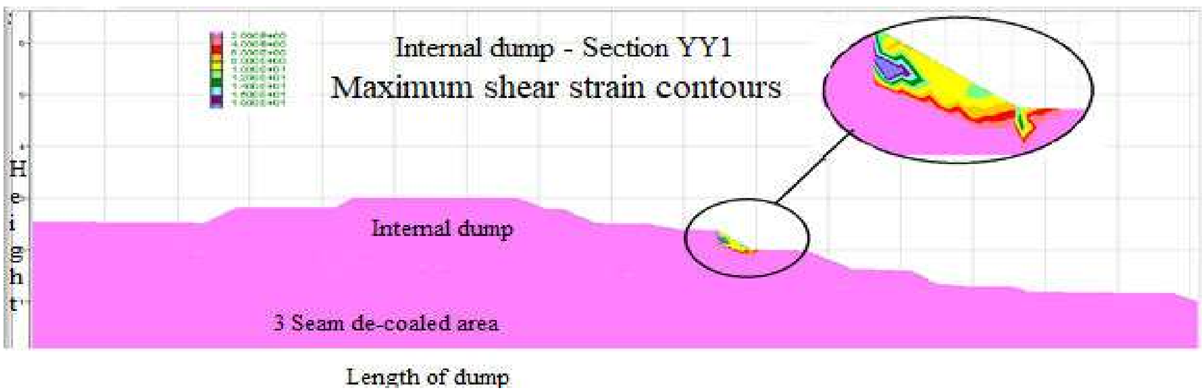


(b)

Figure 13 UDEC (FDM) Analysis a) Computation of Factor of safety (FOS 2.6347) b) Maximum shear strain contours

Case 2 Using RS2 9.0 without addition of fault plane along floor

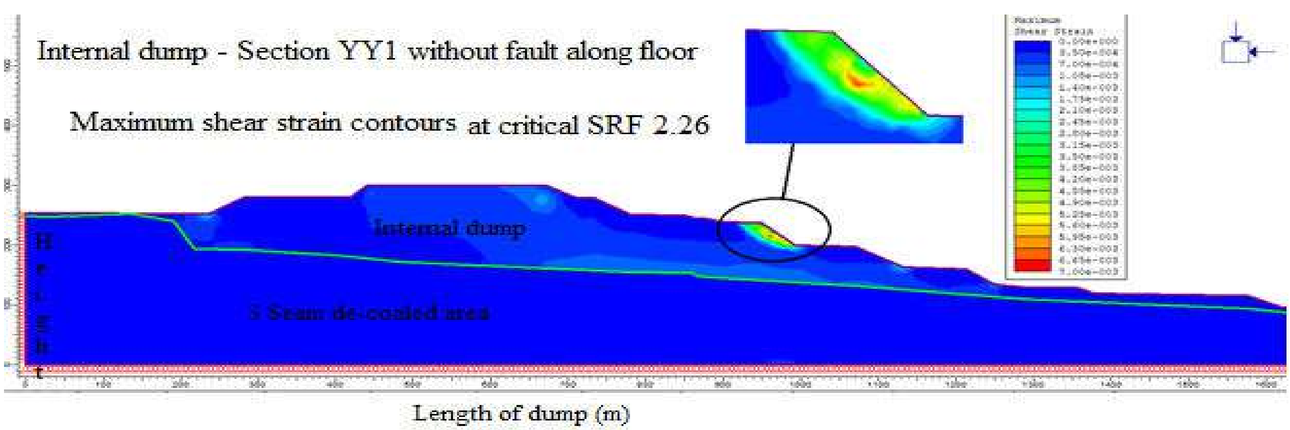
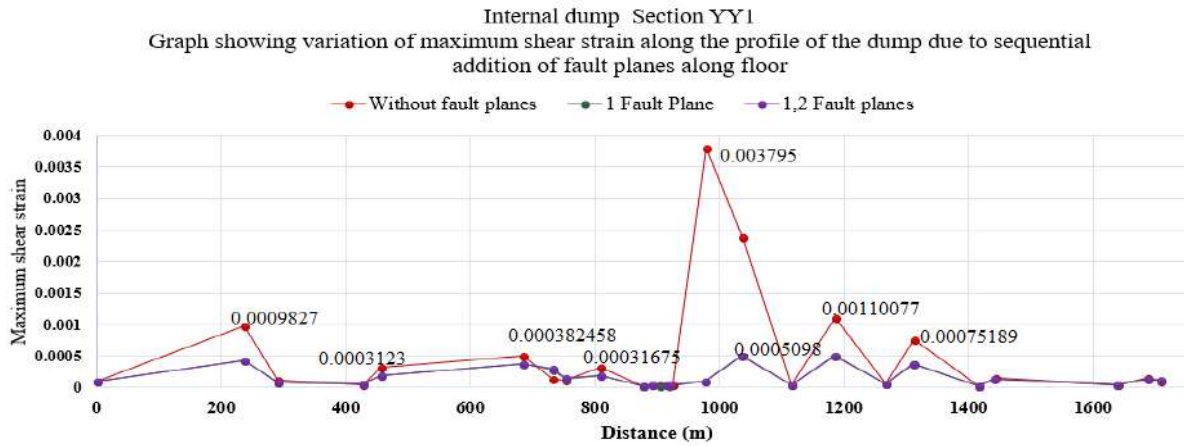
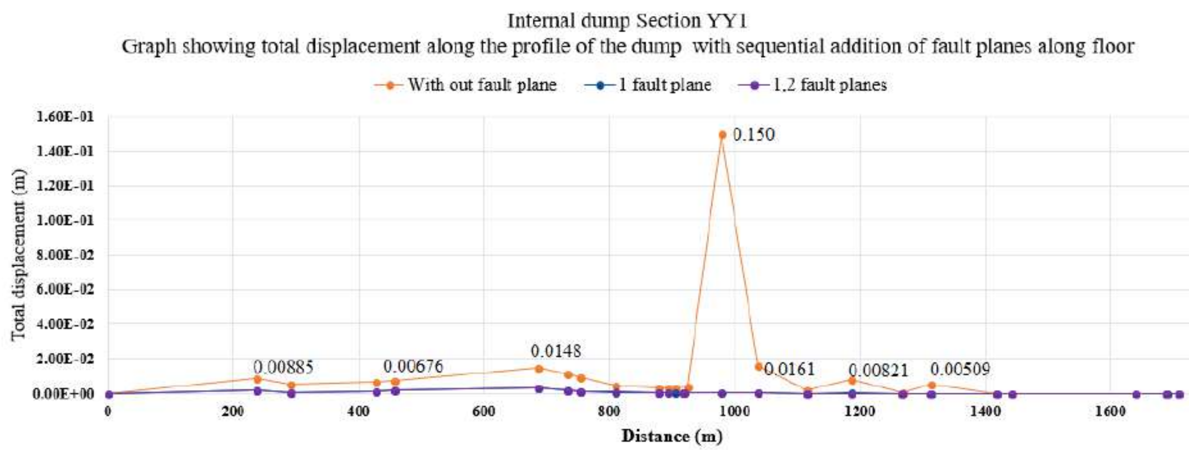


Figure 14 Maximum shear strain contours using RS2 9.0

Case 3 Using RS2 9.0 (FEM) Analysis – Graphs showing variation of maximum shear strain, total displacement along the floor and profile of the dump with sequential introduction of fault planes



(a)



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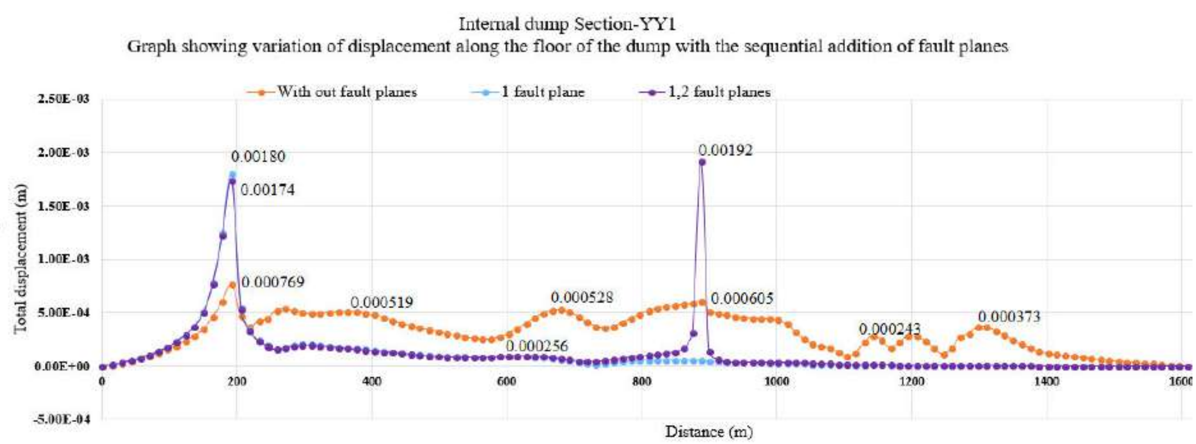

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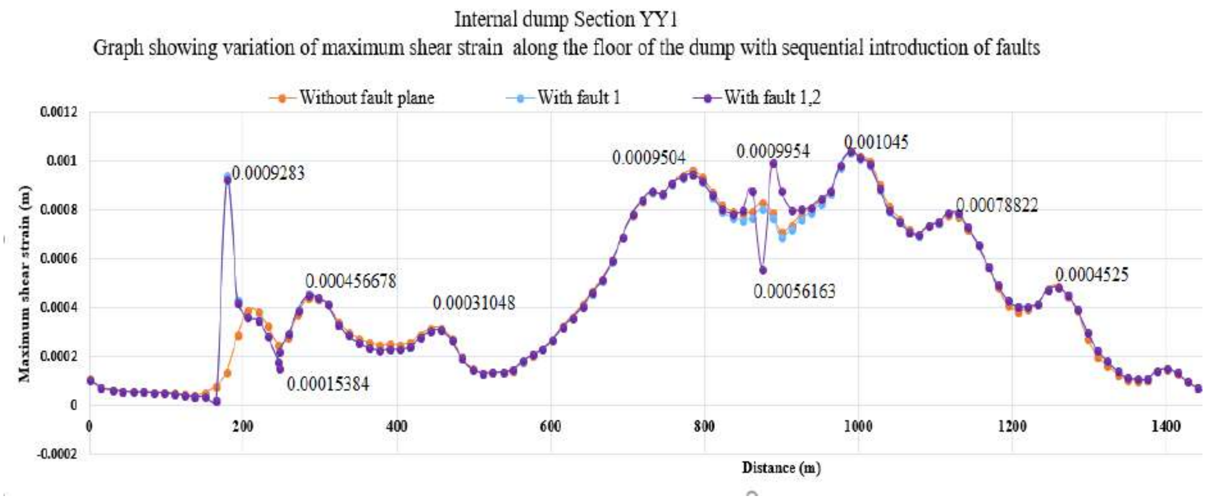

(d)

Figure 14 RS2 9.0 (FEM) Analysis a) Max shear strain along the profile of dump b) Total displacement along profile of dump c) Total displacement along floor of dump d) Maximum shear strain along floor of dump

5.3 The results of factor of safety computed using UDEC and RS2 9.0 with sequential introduction of fault planes along floor of dump are given in the following table

Table 4. FOS values in various scenarios

S. No	Internal Dump Section	Type	RS2 9.0 (FEM) (Strength reduction factor)	UDEC 6.0 (FDM) (Factor of safety)
1	X-X1	No fault plane	2.1	2.403
		1 fault	2	2.37
		1,2 faults	1.997	2.362
		1,2,3 faults	1.97	2.32
2	Y-Y1	No fault plane	2.26	2.6347
		1 fault	2.15	2.469
		1,2 faults	1.99	2.336

6.0 CONCLUSIONS

The stability analysis of internal dump of an opencast mine is essential to create safe working environment. In the present case study, the stability analysis was conducted in coal mines for internal dump under unique circumstances where three geological disturbances viz. three fault planes are present. The study covers the effect of fault planes on stability of dumps.

Based on the stability analysis conducted on internal dump with the presence fault planes

a) With single fault plane the factor of safety changed from 2.1 to 2

b) With two fault planes the factor of safety changed from 2.1 to 1.997

c) With three fault planes the factor of safety changed from 2.1 to 1.97

The above change in factor of safety of internal dump indicates, the effect of fault plane on stability is insignificant.

- Due to presence of all three fault planes along the floor of the dump, maximum shear strain along the profile has reduced from 0.00539 m to 0.000844 m and total displacement decreased from 0.236 m to 0.0197 m, whereas along the floor of the dump the total displacement increased from 0.0000267 m to 0.01396 m and maximum shear strain increased from 0.0019296 to 0.02186 m. This shows that the fault planes are not affecting the stability much, which can be a cause of concern.
- With the variation of maximum shear strain and total displacement along the profile and along the floor of dump due to presence of fault planes, the resultant shear strain and total displacement vectors converges (re-oriented) towards the fault plane. This shows that the orientation of fault planes is such that, it is improving the stability of the dump. Hence, effect of fault planes is favourable.
- In the present case study even though fault planes are present along the floor, the factor of safety of is 1.9, with the dump height of 90 m. Since the statutory requirement of factor of safety is 1.3. So the additional factor of safety can be utilized to increase the height of the dump to an extent of 110 m and for that the factor of safety is 1.35. This will help in accommodating larger quantity of over burden and other financial benefits like reducing the cost of transportation

7.0 ACKNOWLEDGEMENTS

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