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Recovering a Legacy of Old Iron Ore Consolidated Fines Dump on a Mountain Side and Working out a Method of Mining: Conservation of Minerals and Freeing Space

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Abstract

In many of the ore mines, the sub-grade minerals at various times are separately dumped at sites that over time grow into dumps on the downhill side of mountain top. Once regarded as sub-grade, in the times of demand and scarcity they are reclaimed to be sold with blending or directly feeding into furnaces as, most often they are in the form of fines. The slope stability study and safe working remain the key for reclamation and future stability of the fines dump. The work is related to the Study of slope stability of 33.00 Million tonnes of Iron ore dump fines at an iron ore mine in India. The geotechnical study of the present dump slopes as well as a detailed numerical modeling of the proposed pit layout at different stages of mining of the dump has been presented in this article. The study presents a case as to how such old legacy dumps can be mined without compromising safety.

Keywords: *Low Grade Iron ore, Mountainside Dumping, Mine Planning, Slope Stability, Designing for Safety*

1.0 Introduction

Notwithstanding the economic benefits, iron ore mining results in vast volumes of mine waste and residue in the form of waste rock dumps and tailings dams that were largely left un-rehabilitated. These waste dumps leave a legacy that contributes to environmental pollution and ecological degradation through dust and pollution of water resources, which has been witnessed by the public outcry raised by surrounding communities, Non-Governmental Organisations (NGOs) and others[1].

Legacy mine waste dumps negatively affect the quality of life of surrounding communities through air and water pollution, thereby creating health concerns. They create physical barriers to people's security and freedom of movement, which impedes sustainable development programs including illegal mining, minors falling dangerously, drownings in mine water, and accumulations in abandoned holes and voids, and surface subsidence cases[2].

India, the fourth-largest producer of iron ore, has the majority of the mined raw material lying at the mine heads or dumps due to its low iron content. Given that the domestic steel industry only consumes premium iron ore with a grade of 62 percent and above, this sub-grade ore with lower iron content of 58 percent and below, is preferred for exports to markets like China that consume ore of up to 55 percent grade. The general strategy is to blend high value ore with low value ore.

The work is related to providing solution to the challenges of safe mining of a huge dump of low-quality iron ore that has accumulated over a period of 50 years (1958 to 2008). Over such a long period of time about 30-40 MT of iron ore had been dumped on a valley from

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the screening plant of the mine. Dumping was carried out using extended belt conveyors sending the iron ore fines down through the valley which today stands in the form of a dump having a maximum height of 106m from the flat base It has been reported that the base is having a further depth of 20m mostly containing the fines washed out by rainwater but retained by makeshift dams. So, the overall height of the dump is about 126m which may also be different at different points on the periphery of the dump. In a measure to arrest the sediments and water flowing down the dump during rains, four retaining walls have been constructed mostly utilizing the dump material itself primarily not to allow any sediment to flow into the downhill lands and further in to the semi-perennial Karo river

Due to seasonal rainfall the water from the top hills run down through the hill with force making numerous rills and gullies in the dump. The rills and gullies are also likely to change their profile due to further rainfall or any movement that might take place. On the top of the dump there is vegetation growth mostly comprising of Akashmoni plants (*Acacia auriculiformis*) and some other native species. This vegetative growth has provided some strength to the dump and prevented it from heaving. The zone very close to the screening plant has remnants of steel structures including their concrete foundations. A 3.3 kV live power line is running above the dump near the screening plant. The present drainage system is collecting the rainwater from the hill top area and discharging water through the dump. The side walls of gullies and rills are very steep (~80°) rendering the area very unsafe for movement of men and machinery. Previous discharging conveyors used for dumping the fines are now abandoned and a new conveyor system has been installed for the transportation of the material up to the loading point.

While the method of mining of the dump is under consideration, the company has already identified the areas for stacking the mineral to facilitate sale and transport of the material through MDO. Both the stack piles have been already cleared by the company and this has been incorporated in the Mining Plan submitted to competent authorities. The approach roads for transportation of the mineral from the dump to the stockpile and from stockpile to other transportation routes have been defined and construction is in progress.

2.0 Characterization of the Dump Materials by Sampling

2.1 Local Geology

Iron Ore occurring in the deposit belongs to the Precambrian meta-sedimentary rocks. The general succession of strata is as follows:

a. Upper shale
b. Laterite, lateritic ore
c. Iron Ore (Massive, Laminated, Porous and Powdery ores)
d. Banded Iron Formation (BIF) (Hsale/BHQ)
e. Sandstone, Quartzite
f. Ferruginous Shale
g. Lateritiod Manganese Ores
h. Lower Shale.

The dump is not a result of a conventional geological formation, rather it is a result of deposition of iron ore fines of -10mm size produced in the adjacent Duarguiburu Iron Mines. The Iron Ore Fines are carried to the Gua Topailore leasehold by process of natural sliding aided by precipitation. Deposit formed due to accumulation of fines has a length of about 650m and its width varies from a minimum of 130m to a maximum of 260m. The highest RL of the deposit is 570m whereas minimum spread is found up to 470m.Total four numbers of earthen dams has been constructed with the fines material in the deposit to arrest the wash off of fines. Details of all four nos. are given in environmental management plan.

Dump fines (-10mm) have been discarded over a valley for many decades. The nature of surroundings has been given in local geology. However, iron ore body is confined by Banded Hematite Quartzite (BHQ) and shale. As per surrounding nature of litho rocks, lower shale is underlain by iron deposits and BHQ. There is no collapse and failure of in-situ, rocks like BHQ and lower shale has been observed. Thick vegetation with various species has given stability to iron ore and country rocks.

2.2 Description of the Area

Topail ore mining lease which covers an area of 14.15 hectares (35 acres) of land is situated in Gua village of Noamundi Talukain West Singhbhum District of Jharkhand. The mining lease was granted in favour of Indian Iron and Steel Company (IISCO). The Duarguiburu mining lease area is adjacent to Topailore mining lease of area 1443.756 Ha having approximately 7.5 kms length and 2.0 kms width in Noamundi Talukain West Singhbhum District of Jharkhand. The Geomorphology of the terrain is very sloppy, undulating and hilly terrain, with a ridge striking NNE-SSW sloping towards both westerly and easterly. Dendritic drainage pattern with many first order streams are formed at hill top of the mining lease and western parts of the streams are joining to Koina River and Eastern parts the streams are joining to Karo River as shown in the plan of drainage system of Karo and Koina River.

Image 1. Members of the visiting team, Indian Institute of Technology, Kharagpur.

Mechanized mining at Duarguiburu Lease, Gua Ore mines started in the year 1958. There are two products from the crushing and screening plant, i.e. Iron Ore lumps (-60mm to +10mm) and the Iron Ore Fines (-10mm). M/s IISCO at Burnpur steel plant had facilities to consume only the lump ore in iron ore reduction in steel making. Iron ore fines had no use and therefore it was stacked separately by discarding the fines after primary screening of the crushed material at the primary screen level.

For the purpose of geotechnical analysis based on material properties, samples were collected by the IIT KGP experts from two locations: namely, fines dump top and fines dump bottom. The ISRM procedures were generally followed (ISRM, 1981).

2.3 Moisture Content

Moisture content of samples as received from the dump area was determined to know the quantity of water contained in a material. It is used in a wide range of scientific and technical investigations, and is expressed as a ratio, which can range from completely dry to the value of the materials' porosity at saturation.

The results of this investigation are summarized in Table 1.

The result shows that the average moisture content of the samples from bottom fines dump is very low (0.68%) whereas the average moisture content of the samples from top fines dump was 6.83%.

2.4 Specific Gravity

Specific gravity is the ratio of the density of a substance to the density of a reference substance. It is the ratio of either densities or weights and is a dimensionless quantity. The procedure for determination of specific gravity adopted here for the samples is applicable for dump samples composed of particles smaller than 4.75 mm (No. 4 U.S. Sieve) in size. The values are given in Table 2.

Table 2 shows that the specific gravity of samples from both top and bottom of the dump are close to 4.00 (four).

2.5 Particle Size Analysis

This analysis gives the particle size distribution of the dump samples (Table 3). Figure 1 and Figure 2 are plotted for percent finer versus grain-size distribution obtained from the sieve analysis.

It was observed from the graphs that the material at the top of the fines dump had finer particles as compared to the material from the bottom. Fifty percent of the top fines contained particles of less than 625 micron size,

Table 1. Moisture content of dump samples as received

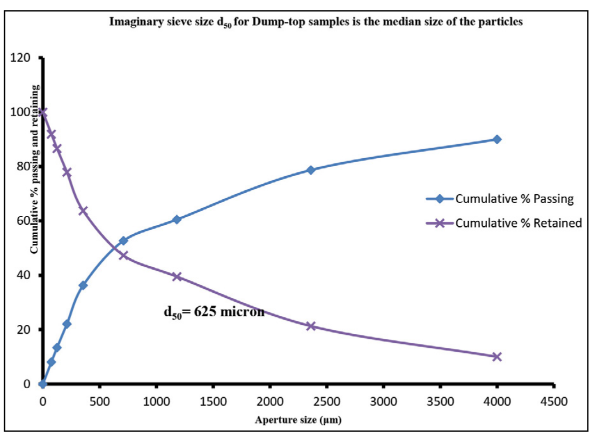
Sl. No.	Sample ID	Petri Dish No.	Mass of Petri Dish	Mass of dish + Soil before drying	Mass of dish + Soil after drying	Moisture %	Av. Moisture %
1	Dump Top 01	1	48.01	145.96	139.14	6.96	**6.83**
2	Dump Top 02	2	39.32	178.97	169.61	6.70	
3	Dump Bottom 01	3	44.56	182.13	181.17	0.70	**0.68**
4	Dump Bottom 02	4	45.18	176.57	175.70	0.66	

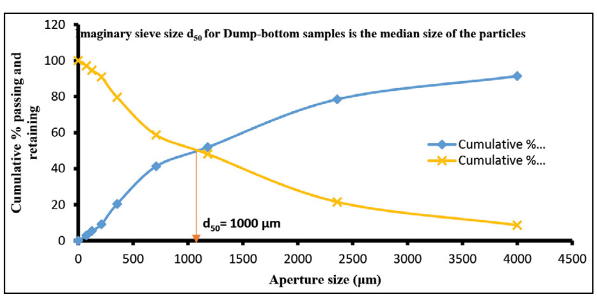
Table 2. Specific gravity of the dump samples

Sl. No.	ID	W_1	W_2	W_3	W_4	$(W_2 - W_1)$	(W_4-W_1)	(W_3-W_2)	(W_4-W_1) - (W_3-W_2)	G	G (Average)
1	Dump-top	30.42	71.03	111.80	81.14	40.62	50.72	40.77	9.95	**4.08**	**4.04**
2	Dump-top	29.57	60.32	102.03	78.95	30.76	49.39	41.71	7.67	**4.01**	
3	Dump-bottom	31.09	70.46	111.03	81.27	39.37	50.18	40.57	9.61	**4.10**	**3.98**
4	Dump-bottom	33.15	79.29	117.43	83.25	46.14	50.11	38.14	11.97	**3.85**	

Table 3. Particle size distribution of dump-top fines

Sample Name- Dump-top fine ore; **Sample weight** = 1000 g									
Sl. No.	**Mesh No.**	**Aperture size (in micron)**	**Mass of empty sieve**	**Mass of sieve + Material retained**	**Material retained (in g)**	**% Retained**	**Cumulative % Retained**	**% Passing**	**Cumulative % Passing**
1	5	4000	500	600	100	10.00	10.00	90.00	90.00
2	8	2360	438	551	113	11.30	21.30	88.70	78.70
3	16	1180	375	557	182	18.20	39.50	81.80	60.50
4	25	710	385	463	78	7.80	47.30	92.20	52.70
5	45	355	332	496	164	16.40	63.70	83.60	36.30
6	70	212	329	471	142	14.20	77.90	85.80	22.10
7	120	125	333	420	87	8.70	86.60	91.30	13.40
8	200	75	322	375	53	5.30	91.90	94.70	8.10
9	pan	0	308	389	81	8.10	100.00	91.90	0.00





Figures 1 and 2. Grain size distribution of dump-top fines.

while fifty percent of the bottom fines contained particle size less than 1000 micron.

2.6 Unit Weight

Proctor compaction test was carried out to find out the degree of compaction of a dump material which is expressed in terms of its dry unit weight. The test consists of *compacting* the dump sample into a standard mould using standardized compaction energy at several different levels of moisture content. The grain-size distribution, shape of the grains, specific gravity of dump solids and amount and type of clay materials present affect the maximum dry unit weight and optimum moisture content.

Table 4 summarizes the values of dry unit weight of compaction in g/cc of each type of dump samples.

The dry unit weight after compaction increases in the beginning with the increase in moisture content as shown in the graphs. However beyond certain moisture content, any further increase in the moisture content tends to reduce the dry unit weight. This phenomenon occurs because the water takes up the spaces that would

Table 4. Summary data of proctor compaction test of dump samples

Sample No.	Sample ID	Cohesion (kPa)	Angle of internal friction (degree)	Dry unit weight of compaction (g/cc)
1	Dump-top Fines	135.38	16.47	2.70
2	Dump-bottom Fines	68.18	32.78	2.67

Table 5. Cohesion and angle of internal friction of the fine dump samples

Sample No.	Sample ID	Cohesion (kPa)	Angle of internal friction (degree)
1	Dump-top fines	135.38	16.47
2	Dump-bottom fines	68.18	32.78

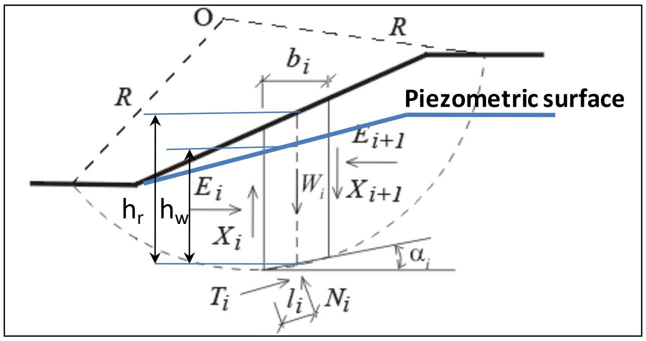


Figure 3. Bishop's simplified method of slices.

have been occupied by the solid particles. The moisture content at which the maximum dry unit weight is attained is generally referred to as the optimum moisture content. The results indicate the samples can be compacted up to maximum dry densities of 2.70 g/cc and 2.67 g/cc when moisture contents of the top and bottom samples are 11.0% and 14.10% respectively.

2.7 Cohesion and Angle of Internal Friction

Direct shear test is a laboratory test used to measure the shear strength properties like shear strength, cohesion and angle of internal friction of soil and dump type material. Table 5 summarizes the values.

It may be seen from Table 5 that friction angle of the top fine is less than the bottom fine dump while cohesion of the top fines is more than the bottom fines because top dump samples are having more fine particles compared to the samples collected from the bottom of the Dump.

3.0 Stability Analysis of Dump Slope

3.1 Classical Analysis of Slope Stability

The simplified Bishop method has been widely used in slope stability analysis and is regarded as the one of the best methods of limit equilibrium for calculating the factors of safety of circular slip surfaces (AW Bishop). The Bishop method, assumes that the total normal force is at the centre of the cutting edge and can be determined by plotting the force on the section vertically or normally. In this method, the interslice forces are assumed to be horizontal, or the vertical interslice forces are neglected, the vertical force equilibrium and the moment equilibrium about the centre of the circular slip surfaces are satisfied, but the horizontal force equilibrium is not considered[5].

The Simplified Bishop's Method is an extension of the Method of Slices and is generally used for calculating Factor of Safety (FoS) of slopes. As shown in Figure 3, weight of i^{th} slice (W_i) acts vertically downward. The resistive force (T_i) and normal force (N_i) act at the base of the slice. It is reasonable to assume that forces on the sides of each slice are horizontal and no shear force exists at the vertical sides of the slice. The problem becomes suitable for equilibrium studies. The Factor of Safety or Safety Factor (SF) can be expressed by the following equation which is derived from Bishop's Method:

$$SF = \frac{\sum_i \frac{\left[c' + \left((W_i / b_i) - r_{u_i}\right)\tan\varphi'\right]}{A_i}}{\sum_i (W_i / b_i)\sin\alpha_i}$$

Where, SF is the safety factor,

$$A_i = \cos\alpha_i + \frac{\sin\alpha_i \tan\varphi'}{SF}$$

c' is the cohesion, φ' is the internal angle of internal friction, b_i is the width of each slice (assuming that all slices have the same width), W_i is the weight of each slice, r_{u_i} is the pore water pressure of each slice and is expressed as $r_u = \left(\frac{h_w}{h_r}\right)\left(\frac{\gamma_w}{\gamma_r}\right)$, γ_w and γ_r are bulk density of water and geo-material respectively. The parameters, h_w and h_r are height of piezometric surface and that of slice respectively. Safety Factor (SF) is obtained by iterative method. An initial value of SF is assumed and then Newton-Raphson or other iterative techniques are applied to estimate the final *SF* until difference between *SFs* for two consecutive iteration is minimal.

3.2 Description of Existing Dump Slope

The plan view of the existing dump site has been shown earlier in Figure 2. Seven typical sections 30 degrees apart on both sides of a hypothetical centre line of the existing dump slope, namely; S-1, S-2, S-3, S-4, S-5, S-6 and S-7 are considered for numerical analysis to evaluate the present factor of safety of the dump slope. The profile and dimensions of the slope for all sections are provided by the concerned department of the Gua Iron Ore Mine. Based on this information, the geometrical profiles of the slopes along all sections are depicted from Figure 5 to Figure 11.

4.0 Description of Proposed Dump Slope with Mining Pits

Among all the seven sections, section S-3 along the hypothetical centre line of the dump is considered for study as illustrated in Figure 12. S-3 is chosen because it can show all the benches in the bottom pit. The mining pits will look similar, but not same, as in this section, as in Figure 13. Here, four slopes namely Slope 1, Slope 2, Slope

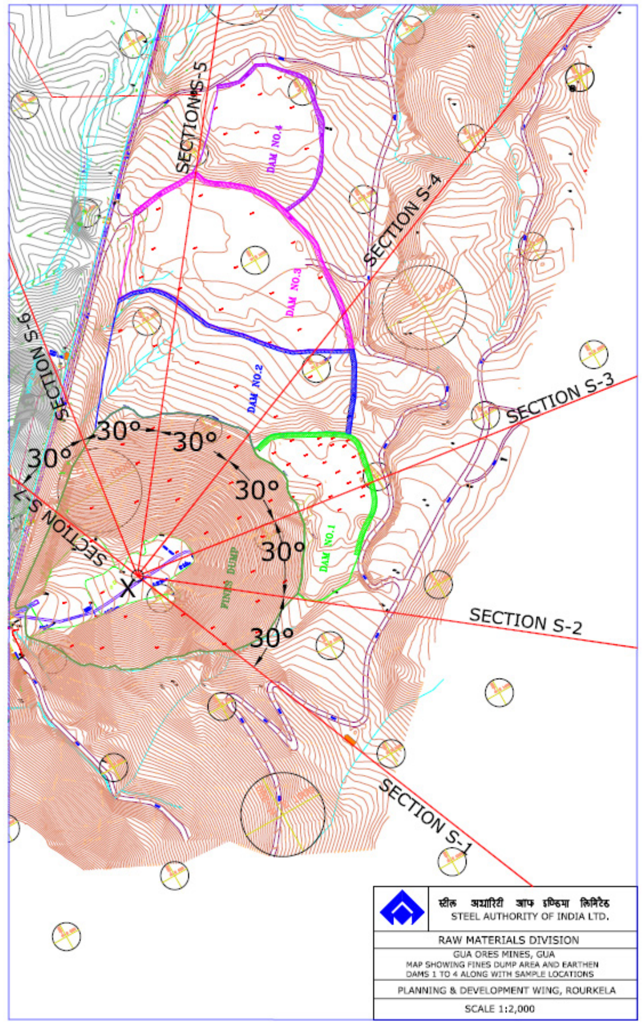


Figure 4. Existing dump site PLAN.

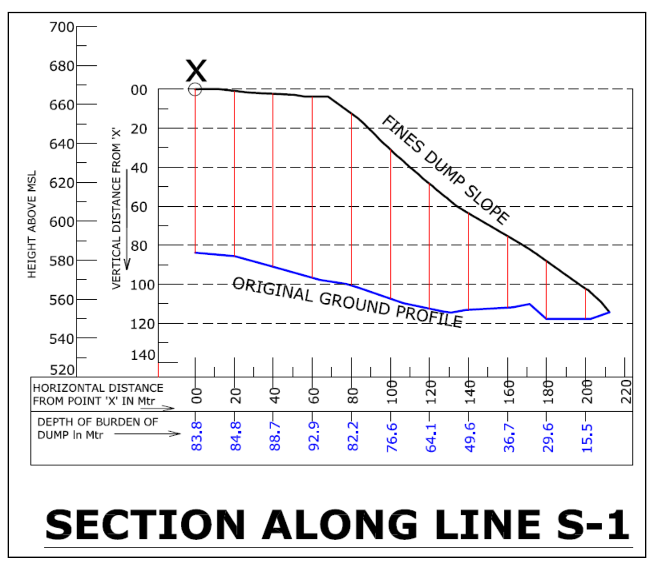


Figure 5. Section along line S-1.

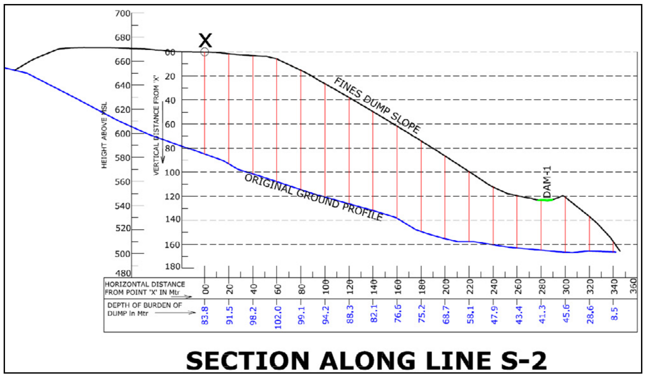


Figure 6. The section along line S-2.

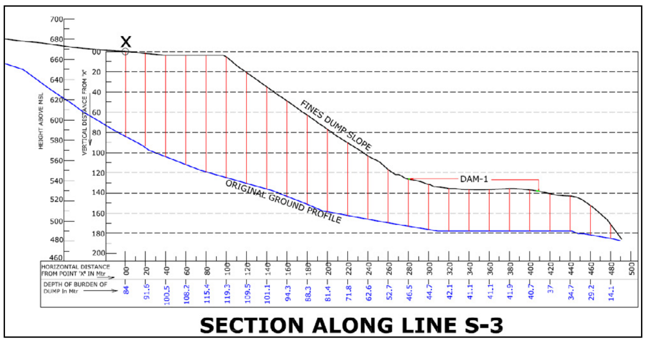


Figure 7. The section along line S-3.

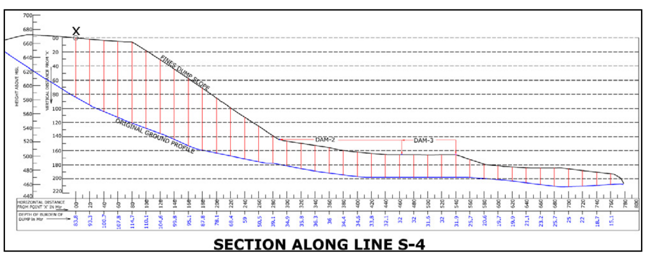


Figure 8. The section along line S-4.

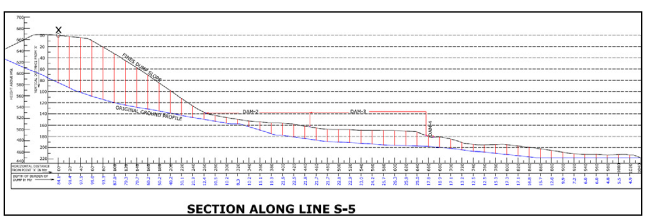


Figure 9. The section along line S-5.

3 and Slope 4 are considered for initial phase of working. Slope 1 will commence from hill side having 10 benches (height 4m, width 12m and bench angle 38°) with a berm in the middle having a width of 25m. Similarly, Slope 2 have been designed for 5 benches which will start from

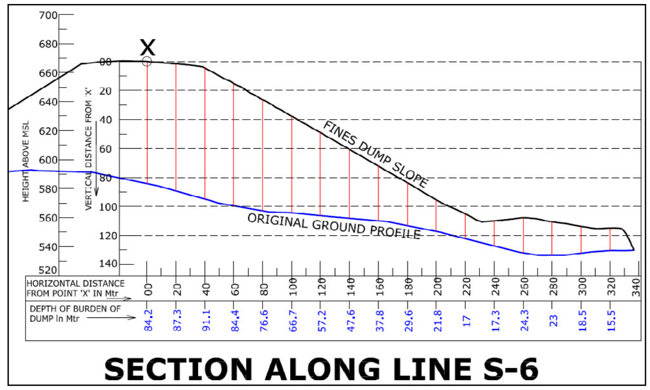


Figure 10. The section along line S-6.

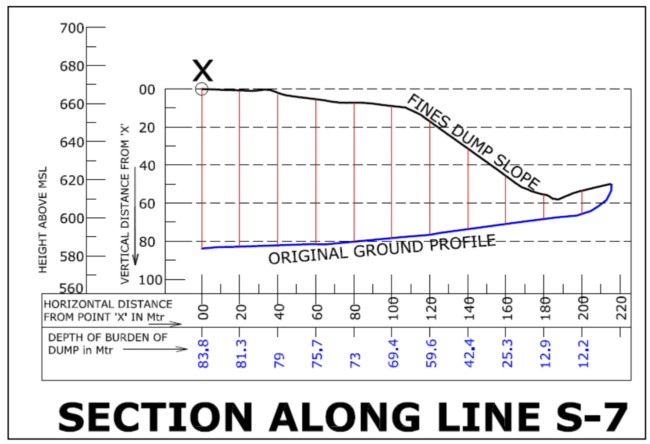
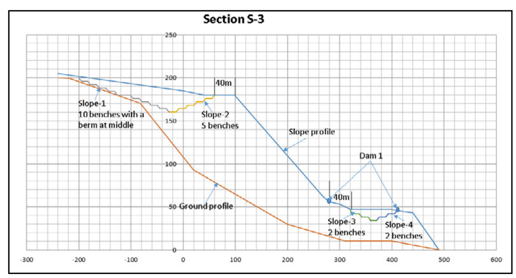


Figure 11. The section along line S-7.



A minimum 40+180+40 m=260m width block will be left all along.

Figure 12. A generalized slope along the S-3 section (all in scale).

40m behind the edge of the main existing slope. Again on the bottom side of the dump, leaving 40 m from the toe of the main slope, Slope 3 will start.

The above results as in Table 6 show that for sections S-4 and S-5, factor of safety was only 1.24 and that of S-7 was 2.59. Another major area of interest is S-3 and S-4 that didn't show any change in factor of safety with 100t. Of course, the FoS (1.4 was 1.24) are not acceptable for engineering design. A minimum FoS of 1.50 at all times

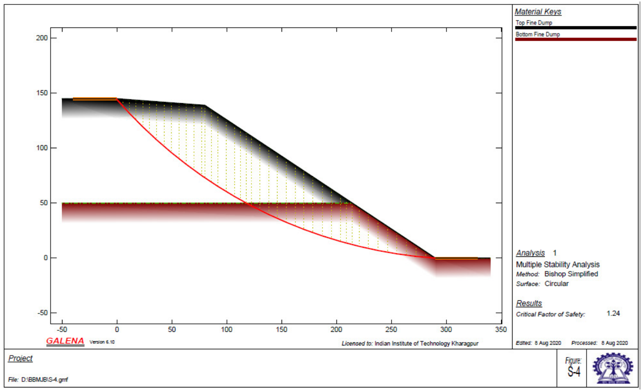


Figure 13. The factor of safety of the existing slope along the S-3 section.

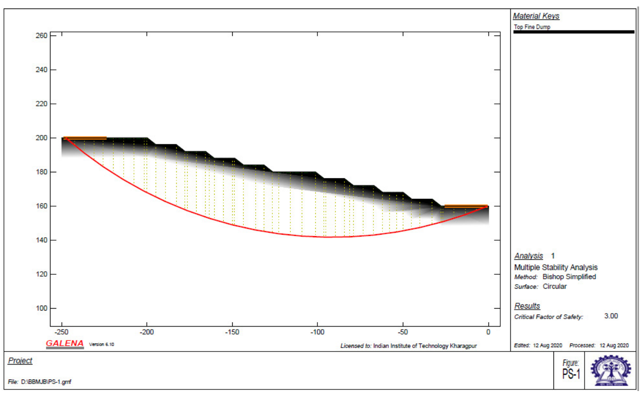


Figure 14. The factor of safety of proposed slope-1 along S-3 section.

of operation is always desirable. This is the reason it was decided that the dumps cannot be worked with one large pit.

5.0 Stability Analysis of the Proposed Slopes with Benches

As said earlier, stability analysis of the proposed layout comprising of all the slopes for S-3 section has been carried out. The geotechnical properties of the dump materials as determined through laboratory test were used for stability analysis. The modeling strategy in general is to use properties of the dry sample. The S-3 section is shown in figure 14. The proposed slope profiles in dry condition for S-3 section without any load and the proposed slope profiles in dry condition for S-3 section with 500t load. The results from the models are summarized in Table 6.

Table 5. Summarized factor of safety (FoS) for existing slopes

Sl. No.	Section Name	Factor of safety (without load)	Factor of safety (with load)
1	S-1	1.26	
2	S-2	1.40	
3	S-3	1.40	1.40
4	S-4	1.24	1.24
5	S-5	1.24	
6	S-6	1.71	
7	S-7	2.59	

Table 6. Summarized of Factor of Safety (FoS) for proposed slopes of section S-3

Sl. No.	Slope Name	FoS without load	FoS with Load
1	Slope-1	3.00	2.75
2	Slope-2	3.74	2.46
3	Slope-3	5.25	2.19
4	Slope-4	5.25	2.17

It is clearly evident from the above results that for the benches in the proposed layout, Factors of Safety ranged from 3.00 to 5.25 without additional load. It was also observed that the Factors of Safety ranged from 2.17 to 2.75 with a very high load of 500t incorporated for testing the reliability of the slopes. As a matter of precaution, dam side mining should start only after reducing the effective height of the Hill-side Pit (Slope -1 and 2) by at least 15 m (or four benches). This will ensure further safety of the mining operations on the Dam-side pit. Reducing the height of the middle ridge left in the first phase completion of the top section mining is necessary for further reducing the load on the bottom pit, to improve FOS. Later on, dozers towards the slope side, rolling the material to the bottom on the 40 m barrier, will safely remove ore from the top pit, of an approximate height of 20 m and the same can be collected from the bottom - thereby ensuring safe removal of the ores from the leftover part. A technical study may again be required at this point to assess the situation. Now on the nearly leveled ground, similar pit benches will be established and top section mining will continue as in earlier pit. The process will be repeated until the low grade ore can safely be mined.

6.0 Run-off Management

The workings, benches, roads and sumps should be so managed that run-off water is allowed as much less as possible to enter and flow on the slopes of the dump. Water from outside the top mine pit must not enter the mine area as far as practicably possible. The top dump pit water should be channeled to the outer side of the mine through sump. The water running from the long dump slope should not be allowed into the bottom pit. A properly maintained garland drain at the toe side of the dump should be constructed to course the flowing water away from the mine and without interruption in to the nearby stream. During rainy season when there will be no mining, some flood control provisions and water level monitoring should be planned to avoid flooding downstream. The water in the bottom pit will be managed by a sump connected to a drainage.

7.0 Material Evacuation

In the absence of available space for the construction of a road from the top the dump, a belt conveyor may be installed to evacuate the material from the top, from the right mountain side, from the existing crusher position, and then the bottom till the identified stockpile area. This will also help reduce the environmental pollution as caused by the diesel dump trucks.

8.0 Setting the Mining Code

On the basis of the Part-A and Part-B studies the following is considered foras tyo how the mining will be carried out:

1. The designated top fines dump and the bottom fines dump cannot be worked out as a single mine pit because of the low factor of safety as found in most of the sections. The combined F.O.S. was below 1.5 and hence cannot be allowed to mine as a single pit.
2. It is advised to work out two pits, one at the top and another at the bottom, with a minimum horizontal distance 240 m between the internal boundaries of the working.
3. Though the pits will not be worked during the rainy season due to low overall factor of safety, occasional heavy rains in non-rainy seasons may trigger slope failure. An inspection based slope failure damage assessment and control will be in place, the details of which are given below.
4. It must be emphasized that the team did not have any idea of the dumped material at different depths. As can be seen, the haematitic material has been completely oxidized, liquefied-solidified, compacted on the surface into a nearly impermeable structure but the team did not have any idea as to how far in depth this compaction phenomena has reached. At a depth, the material can still be loose. With this idea, the calculation has been based on semi-compacted material, liable to lose strength due to inherent moisture and added moisture due to any rain event.
5. The top dumps slope will be started first and with time it is supposed to ease the normal load as well as horizontal load of the complete dump, ensuring better overall Factor of Safety.
6. Once the two pits are complete as per the proposal, the experience of the working can be used to plan for the excavation of the remainder of the dumps after a technical study.

9.0 Safe Operational Practice for Dump Slopes Condition Assessment and Prevention of Failure and Hazards

1. Mine manager in consultation with the Safety Officer and other mine officials shall appoint a team of qualified persons including assistant managers and above, having at least 2nd class Mine Managers Certificate of competency, and with one or two qualified Civil/Mechanical Engineers/ overman (certificate holder) to periodically review the conditions of the mine slopes: ultimate and operating unbroken mine and overburden slopes and benches, broken stockpile slopes –as within the scope of the study.
2. The Slope stability team must work in close liaison with the Safety Committee.
3. The period of review on dry months of October to May, should be once in 2 weeks whereby every slope will be assessed for safety inspection and assessment that will be properly recorded and signed, and shall remain with the office of the

Manager. The Manager will be reported of the details every time in writing of whether the slope conditions have changed off late or changing rapidly.

4. The period of review for predominantly rainy and wet months of June to September the inspection shall be nominally carried out once every week. The Manager will be reported of the details every time in writing of whether the slope conditions have changed off late or changing rapidly. The period between successive inspections by the team shall increase with heavy rain predictions at any time.
5. The features of impending slope failure indications are:
   - I. High water seepage from wide areas on the slope areas and from the toe,
   - II. Continuous rolling down of rock blocks from the top.
   - III. Excessive and increasing slurry flow from one place or from several places in the toe and face of the slope.
   - IV. Increasing number of rill and gullies in short period of time of few hours and days,
   - V. Visible swelling of and separation from the layers, and
   - VI. Visible surface cracks developed and extending in short period of times from one part to another.
6. The mine management must make a checklist of indications of slope failure or collapse that need to be looked into in situations where the slope unstability can be out of control.
7. The history of slope failures point that most of the failures take place in the period of incessant rains or immediately after such rain episodes. Events of short period heavy rainfalls and events of medium to heavy period rainfalls are to be particularly taken care of. The office of Area Safety Officer shall heed to such forecasts, now reliably available on the net and media, and direct and participate with the team to make at least one inspection every 24 hours or less, as found necessary. In such event, all operational places should be immediately cleared of workmen, property and asset. The team should document and report any such instances to the manager of the mine and if they are unanimous in voicing dangers of slope failure, the Manager should take immediate action to save the workmen and property and restrict work till all clearance reports are tabled.
8. Any alarm or alert raised by the team and the guidance by the team headed by the Safety Officer must be reported in writing to the Manager to take actions, as may be found necessary, related to stoppage, and evacuation of people, equipment and other assets. In no occasions, the manager should either take or encourage unsafe acts or daredevilry to maintain production at the cost of workmen and property.
9. A Trigger Action Response Plan (TARP) followed by disaster management response plan have to be established to respond to any major eventuality.
10. The team should also listen to the mine workers on the sites, and should engage discussions to look for features that can be considered dangerous and that need appropriate actions.
11. All such actions must have to be reported appropriately to DGMS as per the law prescribed.

10.0 Conclusions

The study shows that a mining scheme for a sub-grade iron ore dump is possible with sufficient safety concern. Another potential advantage is to free up locked up spaces,held with dumping.

Beneficiation of sub-grade iron ore will help the global steel industry by maximizing resource utilization, reducing costs, enhancing supply security and thereby boosting production capacity. Domestic steel players would be less dependent as they are on imports once sufficient higher-grade ores are available for use.

For any country, the process will also discourage exports of the raw material, depriving exporting steelmakers access to domestic iron ore supplies and help the domestic steel makers to get a better cost advantage. According to reports, in 2022, the Indian mines ministry recommended steps for beneficiation. The recommendation said at least 80 percent of the low-grade ore (with less than 58 percent iron content) produced annually should be upgraded to higher-grade ore (with 62 percent iron content). It also proposed fines and potential termination of mine leases if the target was not met.

11.0 References

1. Nair A. How the steel industry will benefit from beneficiation of sub-grade iron ore. 2024. https://www.moneycontrol.com/news/business/how-the-steel-industry-will-benefit-from-beneficiation-of-sub-grade-iron-ore-12729220.html
2. Das MR, Satapathy S, Pothal LK. A study on waste management in iron mining. Materials Today: Proceedings. 2023.
3. ISRM. Rock characterization, testing and monitoring E.T. Brown (Ed.), ISRM Suggested Methods, Pergamon Press, Oxford. 1981.
4. Bishop AW. The use of the slip circle in the stability analysis of earth slopes. Géotechnique. 1995; 5(1):7-17.
5. Johari A, Mousavi S and Nejad AH. A seismic slope stability probabilistic model based on bishop's method using an analytical approach. Scientia Iranica A. 2015; 22:728-41.