Optimum Dump Slope Design of a Lumpy Chromite Ore Mine

Singh, V.K.
Scientist
e-mail: vks_slope@yahoo.com
Slope Stability Division, Central Institute of Mining and Fuel Research (CIMFR), Dhanbad

ABSTRACT

The geotechnical study and slope design of the dump slopes at Sukinda open cast mine, Orissa has been discussed in the paper. The relevant geotechnical properties of the dump materials were tested at the rock/soil mechanics laboratory of CIMFR. The ground water condition was estimated. The slope stability analysis was done with the help of GALENA software. It was also aimed to know the influence of slope design parameters on the safety factor by sensitivity analysis, which tells the importance of the parameter in the slope. A more justified and suitable remedial measure can be planned for any critical slope after sensitivity analysis.

1. INTRODUCTION

The Sukinda Chromite mine is situated in Orissa state of India and is owned by M/s. TATA STEEL. The mine is fully mechanized. Shovel dumper combination is used for overburden removal as well as ore mining. A geotechnical study was carried out to determine the optimum dump height and its overall slope angle. It was also aimed to know the interplay and effect of the input parameters of slope design on the factor of safety, which tells the importance of the parameter in the slope. Based on this sensitivity analysis a more justified and suitable remedial measure, which takes care of the critical parameter, can be planned for any critical slope. As per the mine management, there is no case of dump failure in the past.

The Sukinda opencast mine is in sub-tropical climate. The average annual rainfall is 1200 mm. 95% precipitation results in run-off away from the dumpsite. There is no perennial source or channel of water near the dumps.

2. GEOMECHANICAL PROPERTIES

The samples of foundation and dump material were collected from different parts and depths of the already existing dumps. The direct shear tests have been conducted in the soil mechanics laboratory of CIMFR. The modal values of bulk density and shear strength parameters are presented in Table 1.

<table>
<thead>
<tr>
<th>Material</th>
<th>Bulk Density (kN/m³)</th>
<th>Cohesion (kPa)</th>
<th>Friction Angle (degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drained Geo-mining condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limonite (Foundation)</td>
<td>13.3</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>Dump Material (Quartzite)</td>
<td>19.1</td>
<td>34</td>
<td>27</td>
</tr>
<tr>
<td>Undrained Geo-mining condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limonite (Foundation)</td>
<td>14.5</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Dump Material (Quartzite)</td>
<td>20.0</td>
<td>29</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 1: Geo-mechanical Properties
The mode of failure in the slopes of the dumps was categorized as circular type of failure. The cut-off value of safety factor was selected to be 1.3 for the dump slope design (Hoek and Bray, 1981). The height of the dump should be measured from the lowest RL of the dump foundation in in-situ condition, from any direction of the dump. If the dump is placed on loose/ filled/ previous dump, then the lowest RL should be considered at the base of this loose/ unconsolidated material because any failure will take away this loose material also.

The analysis was done to determine the maximum possible dump height consisting of quartzite (Figure 1). The stability analyses show that 80m high dumps have 1.3 safety factor. The dump should be developed in three lifts (Figure 1). The first lift should be 30m high while second and third lifts should be 25m each high. The bench width between the two lifts should not be less than 12m. The angle of repose of the dump material was measured to be about 40 deg. at different locations of the pit.

Fig. 1: Stability Analysis of 80m High Dump in Three Lifts

The dump has been developed with above-mentioned parameters (Figure 2). The following remedial measures were also recommended and implemented for long-term slope stability of dumps. The dozing and grading up to 0.5 m depth of the top surface, at the proposed dumping location, was done. It was necessary to avoid dump foundation failure. The dumps have been developed by keeping safe distances from any permanent structure or any type of working. This distance has been not less than the height of the dump measured from the toe (at the lowest level) of dump in in-situ condition. The top surface of the dump is being covered with topsoil. Once the top surface is completely covered, the local species of self sustaining plants would be grown on the dumps.

4. SENSITIVITY ANALYSIS AND DRAINAGE

The sensitivity analysis was done with an aim to know the influence of water condition on the factor of safety. The influence of groundwater on factor of safety is remarkable. The dumps are stable in drained geo-mining condition with cut-off safety factor of 1.3. The safety factor of the same slope reduces to 1.19 in undrained geo-mining condition. So in undrained geo-mining condition the dump slope would be unstable. However, it may be recalled that the most likely geo-mining condition of the slope was already adjudged to be drained geo-mining condition. The slopes are likely to be stable with available shear strength of dump material in this geo-mining condition. In order to avoid undrained geo-mining condition, proper water management both at the dump foundation level and dump-top surface has been ensured for quick run-off of water.

5. SLOPE MONITORING

The slope monitoring allows failures to be predicted and safe working conditions. The review of monitoring results, visual inspection and regular briefing of field people help to detect the onset of failure. The slope monitoring, of dumps more than 40m height, is being done by the mine management with the help of total station surveying equipment. Till date no large-scale failure is reported.

6. CONCLUSIONS AND RECOMMENDATIONS

An assessment of the engineering geology, strength properties and the related geotechnical controls indicated that 80m high quartzite dumps are likely to be stable if these are developed in three lifts along with the implementation of the following remedial measures. The first lift should be 30m high while second and third lifts should be 25m each high. The bench width between the two lifts should not be less than 12m.

- Proper levelling at the top of the dumped material has been done to minimise the infiltration of water inside the dumps.
- Flooding of the dumps toe has been avoided. A garland drain has been cut all around the toe of dumps to collect run-off of the rainwater before it reaches the dump foundation. The drain is properly graded to promote rapid water movement and minimise the chances of ponding.
- The top surface of the dump is being covered with topsoil to support vegetation.

ACKNOWLEDGMENTS

The author is thankful to the mine management for providing all necessary facilities and information during the study. He is grateful to the Director, CIMFR, Dhanbad for permission to publish this paper in IGC2010.

REFERENCES