EVALUATION OF STABILITY OF DUMP SLOPES THROUGH OBSERVATIONAL AND MUMERICAL MODEL APPROACH – CASE STUDY

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ABSTRACT

This paper presents a case study of evaluation of dump slopes in a typical chromate mine in India including observational approaches and numerical modeling besides a critical review of recent accidents due to dump and bench slope failures in India. As per the numerical models, The FOS achieved for typical sections for the North and South dump exceeded 1.2 indicating the stability of dumps in drained condition of slopes except for one section considered in the analysis. As the FOS for the vertical Section - 3000E for the North dump was 1.15, efforts may be made to regrade the dump, accordingly to minimize any scope of further reduction of FOS. However, in saturated condition of slope, there is a possibility of reduction of FOS, which may lead to failure of slope, and hence proper drainage is highly solicited. There is a scope of local slope failure near some of the stations in North and south dumps, in rainy season due to water saturated conditions. Therefore, slope monitoring should be continued to detect the onset of failure so that early and effective stabilization measures can be taken. It is also recommended to regularly produce up-to-date and accurate dump geometry on daily basis for the profile near the target points showing considerable displacement, or if feasible a system for continuous monitoring and construction of Gabion wall may be considered for improved safety.

INTRODUCTION

Chromite mine –A is located in the sukinda valley in Odisha state. A waste dump hasbeen created adjacent to the northern boundary of the Chromite mines lease wherein the excavated overburden mass of the quarry is being dumped. Fig.1 shows condition of the workings during 2017.Maximum height of dump in North and South dumps are about 87 m, and 41 m, respectively. Maximum number of decks in North and South dumps is 6, and 3, respectively. Maximum Deck height in North and South dumps are about 17m, and 15m, respectively. The mine is in sub-tropical climate. The average annual rainfall is about 1200mm, of which 95% precipitation is during the rainy season (June to September), which results in quick run off from the dump area due to sloping topography. There is no perennial source or channel of water near the dump.

The length of the dump is about 680m and width varies from 280 to 350m. The current dump height is about 78m with overall slope angle varying from 20 to 33^0 to the horizontal. The waste dump is benched ranging from 5 to 30m heights. The overburden dump consists of mainly hard and friable laterite, green serpentinite, chart and soft friable brown serpentinite, nickeliferous limonite, C O B tailings and boulders of the hard quartzite. The average cohesion as reported by the mine authorities was 0.49kg/cm, the average friction angle of 30 degreesand the unit weight of the sample 1.8t/m. Fig 2 and 3 detailed Plan view of the South and North dumps, respectively.

Fig.1. Condition of the workings on June 9, 2017 in a typical chromite mine

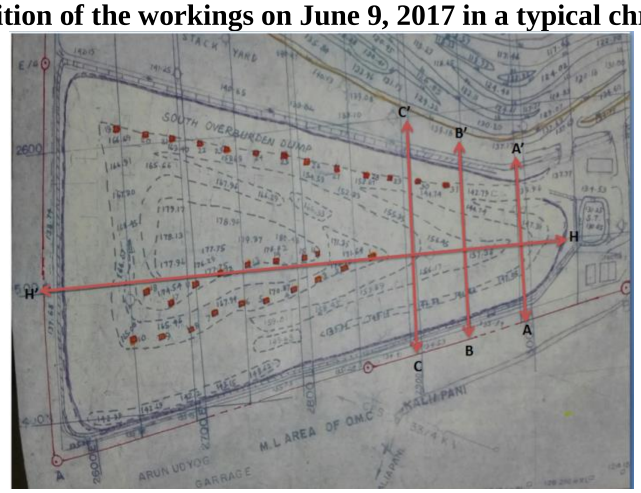

Fig. 2. Plan view of the South dump in a typical chromite mine

Fig. 3. Plan view of the North dump in a typical chromite mine

STABILITY ANALYSIS VIS-A-VIS NUMERICAL MODELING

The stability analysis was done by FLAC SLOPE software, considering three vertical cross sections AA', BB', CC' and one horizontal section HH' for South dump. The factor of safety estimated for the above sections is found to be more than 1.2 indicating stability of dumps. FOS attained for three vertical Sections 2800E, 2900E, 3000E and one horizontal section 3300N the above sections as 1.42, 1.28, 1.15 and 1.47, respectively. The stability analyses were done to determine the slope stability condition of the existing dump with the slope profile shown in the sections. The results of the analyses are presented in the Table 2.

Table.2. Stability analyses of various sections of north and south dump

DUMP	SECTION	Factor of safety (FOS)
SOUTH	A-A'	6.81
	B-B'	1.41
	C-C'	2.49
	H-H'	2.67
NORTH	2800E	1.42
	2900E	1.28
	3000E	1.15
	3300N	1.47

Figure 4 shows the Section of the south dump along the CC'. Figure 5 shows the Simulation output of the south dump along the CC' Section using FLAC Slope with FOS of 2.49 indicating stability of dump. Figure 6 shows the Section of the North dump along the 3000E. Figure 7 shows the Simulation output of the North dump along the 3000E Section using FLAC with FOS of 1.15 indicating stability of dump.

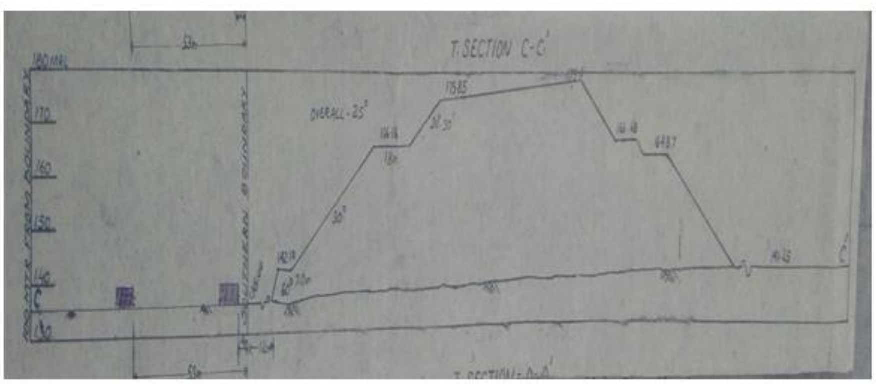

Fig.4. Section of the south dump along the CC'

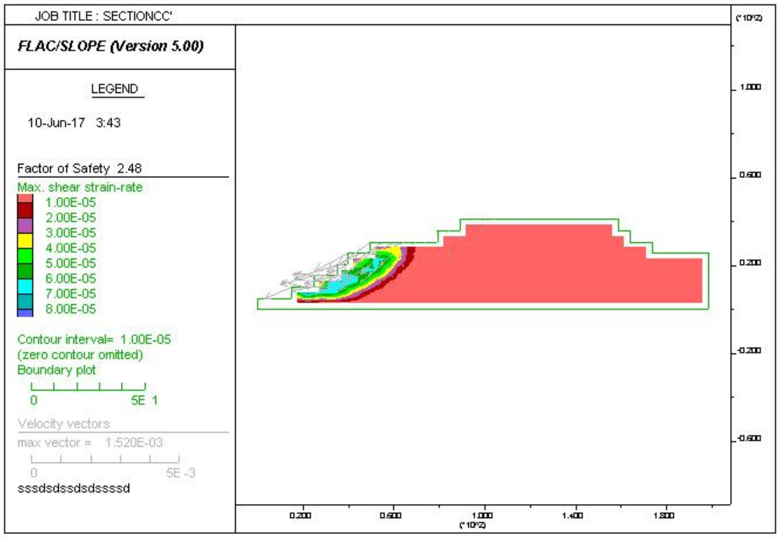

Fig.5. Simulation of the south dump along the CC' Section using FLAC Slope.

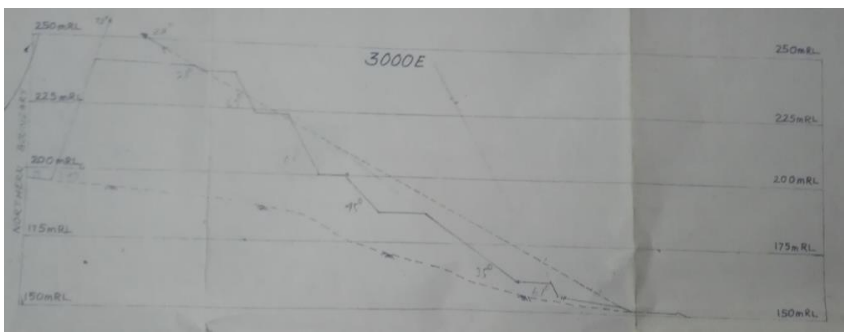

Fig.6. Section of the North dump 3000E

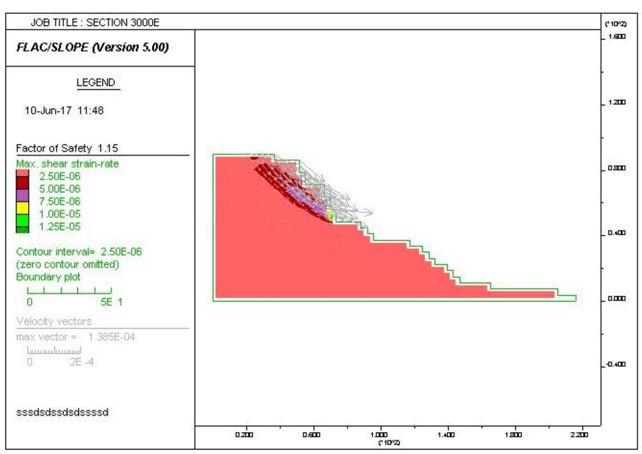

Fig.7. Simulation of the North dump along the 3000E Section using FLAC Slope

Based on above analysis, the FOS achieved for the three vertical Sections 2800E, 2900E, 3000E and one horizontal section 3300N for the North dump was 1.42, 1.28, 1.15 and 1.47, respectively indicating the stability of dumps in drained condition of slopes. Similarly, the FOS reached for the three vertical Sections AA', BB', CC' and one horizontal section H-H'for the North dump was 6.81, 1.41, 2.49, and 2.67, respectively indicating the stability of dumps in drained condition of slopes. In saturated condition of slope, there is a possibility of reduction of FOS, which may lead to failure of slope, and hence proper drainage is highly solicited. As the FOS for the vertical Section 3000E for the North dump was 1.15, efforts may be made to regrade the dump, accordingly to minimize the any scope of further reduction of FOS.

The existing external dump with its profile is likely to be safe in drained condition with good drainage in and around the dump. The dump mass must be maintained in drained condition. Water entry must be checked from entering in to the toe of the dump to avoid inundation of the dump to be providing suitable and effective drainage. Attention must be paid to avoid ~~of~~ rain / surface water in the slope by providing suitable and effective drainage in and around the dump. It should be taken up well before the onset of monsoon.

4. SLOPE STABILITY ANALYSIS VIS-A-VIS OBSERVATIONS BY TOTAL STATION

Dump slopes has been monitored with total station and monitoring stations fixed at an interval of 20 to 50 m on the dumps at a distance of about 1m from the crest of the dump slope (Fig 8). The monitoring stations are located at 25m to 50m interval in the zone of interest and on different levels of the dump. Stability of 31 monitoring stations was installed at south dump and 120 stations in the north dump. Some of the monitoring stations i.e.2/1,7/1 and 10/1 in south is relocated since the formation of bench in progress. The variation in reduced levels and horizontal distance on monthly Basis during April 2017 for south and North dump is graphically represented Figure.9, and 10, respectively. Thirty one monitoring stations are installed and considered for the analysis of stability of south dump. 120 monitoring stations are installed in North dump and 25 monitoring stations along the cross section 3300N were considered for the analysis of the North Dump. These stations are DM – 6, DM – 7,DM - 8 DM - 9/2, DM – 12, DM - 13/1, DM - 14/1 , DM - 15/1, DM - 25/0, DM - 27/1, 25/1, 25/5, 25/6, 25/7/1, 25/8/1, 25/9/2, 25/10/2, 25/11/1, 25/13, 25/14, 25/15/1, 25/37, 25/38/1, 25/50.The Monitoring stations are surveyed with reference to the base station associated with a reference station. The movement of each station is calculated with comparison to the initial reading.

Fig 8: Monitoring of Dump slopes with total station at typical Chromite Mine

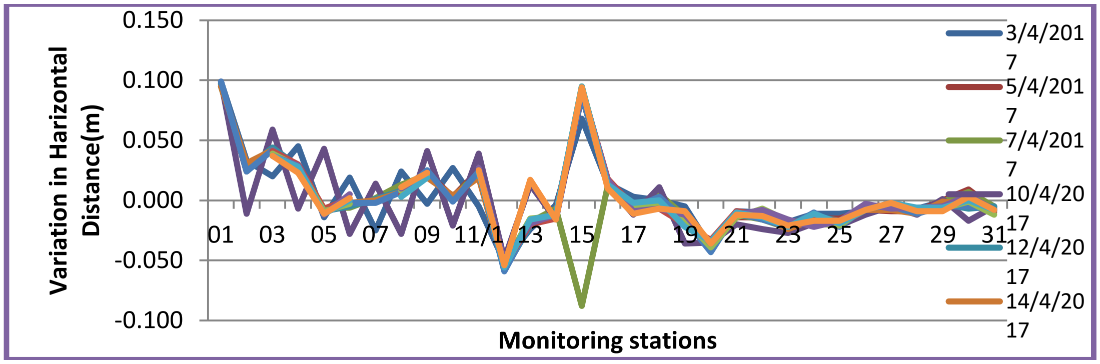

Fig.9. Variation of horizontal distance at south dump during the 3/4/17 to 28/4/17

In South dump, maximum displacement observed in horizontal direction is 126 mm and in RLs is 140 mm. At station # 2, and #12-15 displacements are comparatively more during Jan-Apr'17, thereafter these target points recorded no perceptible movements or any consistent increasing trend at these stations. However, during May'17, stations # 5 to 9, and 19 to 24 recorded comparatively more displacements. The target station #2 (171 m RL) is located at the bottom bench, and # 12-15 (174 m RL) on northern side slope of the South dump while # 19-24 are located on Southern side slope of the South dump. Although the movements in both vertical and horizontal directions are recorded by Total station, there is no consistently increasing rate of movements at the stations. Consistently increasing rate of movements at the stations with more than 25 mm/day on more number of stations in any zone of the dump may indicate probability of mass failure ofslope. Therefore, for those stations with such excessive displacements, it is recommended to regularly produce up-to-date and accurate dump geometry **<u>on daily basis</u>** for the profile near the target points showing more than 100 mm cumulative displacement, or if feasible a system for continuous monitoring of displacements may be used.

In South dump, maximum change in horizontal distance during January, February, March, April and May'17 was 0.052, 0.077, 0.126, 0.100 and 0.034 m, while for the corresponding period, change in RL is 0.098, 0.117, 0.131, 0.14 and 0.086 m, respectively. Except at few points, there is no consistent increase in cumulative displacement or rate of movement with erratic movements of increasing/decreasing trends at different time period indicating possibility of instrument error or local failure/disturbance of the station by external causes such as moving HEMM. Part of these changes may also be attributed to instrumental and/or personal error because the accuracy of the instrument is ±5mm.Visual observations indicated few cracks of about 10 mm width for a length of about 1.5 m near target station #18-19 during end April'17, without any further growth or widening of cracks on south dump, while no perceptible disturbance in North dump. The above observations revealed practically considerable displacement in south dump. However, some of the local movements observed from the Total Station reading may be attributed to high moisture content of materials and deployment of HEMM near to the monitoring stations for the formation of benches in south dump.

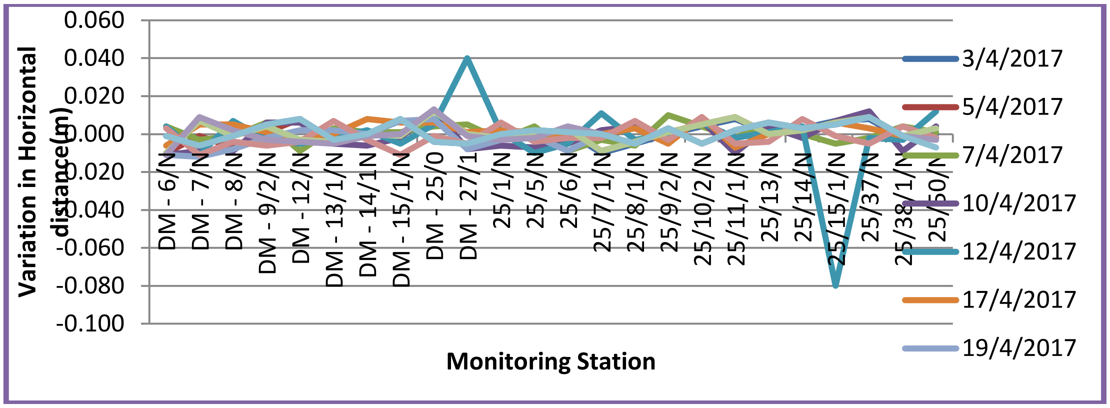

Fig.10. Variation of horizontal distance at North dump during the 3/4/17 to 26/4/17

In North dump, maximum change in horizontal distance for North dump during March, April and May'17 was 0.014, 0.013, and 0.012 m, while for the corresponding period, change in RL is 0.017, 0.014, and 0.019, respectively. Maximum displacement observed in horizontal direction is 14 mm and in RLs is 19 mm. Part of these changes may also be attributed to instrumental and/or personal error because the accuracy of the instrument is ±5mm.

CONCLUSIONS

As per the numerical models, The FOS achieved for typical sections for the North and South dump exceeded 1.2 indicating the stability of dumps in drained condition of slopes except for one section considered in the analysis. As the FOS for the vertical Section - 3000E for the North dump was 1.15, efforts may be made to regrade the dump, accordingly to minimize any scope of further reduction of FOS. However, in saturated condition of slope, there is a possibility of reduction of FOS, which may lead to failure of slope, and hence proper drainage is highly solicited. Local movements observed from the Total Station reading in south and north dump may be attributed due to high moisture content of materials and deployment of HEMM near to the monitoring stations for the formation of benches, and do not reveal any significant mass movement. Therefore, monitoring stations should be carefully protected in such a way that it should not disturbed by the Movement of HEMM, and the monitoring should be done by senior survey officer in regular basis for minimizing the errors in readings. There is a scope of local slope failure near some of the stations in North and south dumps, in rainy season due to water saturated conditions. Therefore, slope monitoring should be continued to detect the onset of failure so that early and effective stabilization measures can be taken. It is also recommended to regularly produce up-to-date and accurate dump geometry on daily basis for the profile near the target points showing considerable displacement, or if feasible a system for continuous monitoring and construction of Gabion wall may be considered for improved safety.

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