Investigation, Design and Construction Methodology of 120 m High IKOCP Dumping Yard, Singareni Collieries

Srikanth Emmadi, G. V. Ramana, and P. S. Prasasd

Abstract The Singareni Collieries Company Limited (SCCL) is a government-based coal mining company jointly owned by the Telangana Government and Government of India. The Singareni coal reserves stretch over an area of 350 km on Pranahita—Godavari Valley of Telangana with a proven geological reserve aggregating to whopping 8791 million tonnes of coal. SCCL is currently operating 29 underground mines and 17 opencast mines in four districts of Telangana. Out of 17 open cast mines, Indaram Khani Open Cast Project (IKOCP) is one of the open cast mine operating by SCCL. Huge quantity of waste/debris (Sandstone boulders, clay and some other rock lumps) is also generated during mining of coal. The SCCL is proposed to construct a 120 m high IKOCP dumping yard in 1.2 km $\times$ 1.0 km of Srirampur Region, near IKOCP, Telangana. Nine bore holes were drilled up to a depth of 7 m at different locations in the proposed dumping yard area. The standard penetration test (SPT) was also carried out during subsoil investigation. The site was investigated and the slope stability analysis of the proposed dumping yard under different conditions was carried out by using GEO 5 software. The present study is intended to highlight the outcome of the study along with suitable design and construction methodology of 120 m high dumping yard based on the field and laboratory investigations.

Keywords Mine overburden · Shear strength parameters · Opencast mine · Dumping yard · Slope stability

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L. Nandagiri et al. (eds.), *Sustainability Trends and Challenges in Civil Engineering*,
Lecture Notes in Civil Engineering 162, https://doi.org/10.1007/978-981-16-2826-9_29

1 Introduction

Due to accelerated industrialisation and extensive growth in population, the energy demand is increased rapidly which forces extraction of coal from open cast mines to serve energy needs. Generally, extraction of coal from mines by open cast mining is relatively better option than underground methods. For successful operation of open cast mine, proper management of overburden mine waste is very essential otherwise it may lead to instability problems. This might affect production of mining operation and safety of human life. For example, pit dumps minimise reusing of overburden material and are effective in utilisation of existing area [1, 2]; however, failure of dump may interrupt quarrying operations, hazard personnel and destroy machinery [2]. In case of material handling and land use, overburden dumps are less effective and overcome the effects of mining operations in case of failure of dump [3, 4]. Many case studies in India reveal that dump failure results in significant damage to quarrying properties, hazard to human life and interrupts coal production [5, 6]. There are dump slope failures occurred at Singareni colliery during December 2009 [7]. In order to provide safety of personnel and machinery, the waste dump should have a proper design [6, 8]. The study area is an open cast mine in Indaram Khani Open Cast Project (IKOCP) and it is operating by SCCL. The SCCL main function is to search and produce the coal deposits along the Godavari valley coal field. Huge quantity of waste/debris (Sandstone boulders, clay and some other rock lumps) is also generated during mining of coal has to be accommodated in minimal area in order to restrict the wastage of useful agricultural land. Hence SCCL is proposed to construct a 120 m high IKOCP dumping yard in the area of 1.2 km × 1.0 km of Srirampur Region, near IKOCP, Singareni Collieries, Telangana, as the waste materials placed in the form of dumps to greater heights. Hence, there is a need to study the geotechnical properties and parameters of dump materials along with foundation soil which governs the design of stability of Dump Yard.

In the present study, field and laboratory investigation has been carried out to evaluate the representative geotechnical properties (shear strength parameters; unit weight) of both proposed dumping yard foundation soil and excavated mine overburden (OB). Slope stability software (GEO 5) has been used to assess the local and global stability of the overburden dump fill. The final slope of the dump yard (overburden dump fill) of 120 m high has been proposed based on the factor of safety value.

2 Geotechnical Investigation on Proposed Site

A total of nine bore holes (BH-1, BH-2, BH-3, BH-4, BH-5, BH-6, BH-7, BH-8 and BH-9) were drilled at different locations in the proposed dumping yard area to find the subsoil strata and its properties of foundation soil. The depth of each bore hole varies from 3.5 to 7.0 m. The location of the bore holes was selected by the

Fig. 1 SPT test on the proposed original foundation site

project authorities at the proposed original foundation site of IKOCP OB dumping yard Srirampur Region Singareni Collieries Company Limited.

2.1 Field Tests

Standard Penetration Test at different levels has been carried out in all bore holes (Fig. 1) and the results are presented in Table 1. Undisturbed soil samples were also collected from each bore hole by using 38 mm diameter tubes. The typical disturbed soil samples from SPT split spoon sampler tube of BH-2 (Label Name: SPT-02 IKOCP) is presented in Fig. 2.

2.2 Sample Preparation and Laboratory Tests

A total of 18 representative soil samples (9 Nos. disturbed soil samples and 9 Nos. undisturbed soil samples) from 9 bore holes (SPT-1 to SPT-9) were collected and conducted grain size analysis, Atterberg limits and shear strength characteristics as per procedures outlined in relevant Indian Standards [9–15] and other standard procedures.

(a) *Physical characteristics of field samples*

The representative samples collected from 9 boreholes were subjected to grain size distribution analysis and consistency limits tests and the results are shown in Table 1. The grain size distribution analysis has exposed that the majority of the soil samples

Table 1 SPT value and physical characteristics of foundation soil

BH. No	SPT value (Ncor)	Depth (m)	Grain size analysis				Atterberg limits			IS soil classification
			< 0.002 mm	0.002–0.075 mm	0.075–4.75 mm	> 4.75 mm	LL	PL	PI	
			Clay	Silt	Sand	Gravel				
1	5–40	1.2–3.45	56	37	7	0.0	68.0	23.0	45.0	CH
2	8–41	1.5–6.0	22	43	35	0.0	38.0	20.0	18.0	CI
3	9–31	1.2–3.9	62	30	8	0.0	70.0	24.0	46.0	CH
4	10–27	1.1–3.35	59	38	3	0.0	74.0	23.0	51.0	CH
5	10–38	1.5–6.0	8	46	44	2.0	0.0	0.0	0.0	ML
6	10–25	1.5–3.4	15	46	39	0.0	30.0	16.0	14.0	CL
7	10–31	1.5–3.45	16	51	32	1.0	30.0	16.0	14.0	CL
8	16–42	1.5–5.55	64	30	6	0.0	78.0	23.0	55.0	CH
9	16–46	1.5–6.9	71	24	5	0.0	76.0	22.0	54.0	CH

Fig. 2 Bore hole number 2 (BH-2)

contain primarily clay fraction then followed by silt and sand (including fine, medium and coarse) fractions barring few exceptions. From the Atterberg Limits tests, it was observed that liquid limit values of the 9 No's of representative soil samples vary from 30 to 78%. Barring one sample SPT-5 (which exhibited non-plastic nature), the remaining 8 representative soil samples exhibited plasticity characteristics and the plasticity index values varied from 14 to 55%. The subsoil samples have been classified as per IS soil classification system and the results are shown in Table 1.

(b) *Triaxial test*

Eight chosen soil samples (Undisturbed) were subjected to Triaxial Shear Test (UU test). The soil samples were sheared at three various confining pressures of 1.0, 1.5 and 3.0 kg/cm^2 respectively. The values of shear strength parameters, i.e. cohesion (c) and angle of internal friction (φ) of the tested soil samples of the areas are shown in Table 2. The values of shear strength parameters, i.e. cohesion (c) and angle of

Table 2 Foundation investigations at the original ground site of IKOCP

SI. No	Field No.	Depth (m)	In-situ bulk density kN/m^3	In-situ dry density kN/m^3	Natural moisture content %	IS soil classification	Shear strength parameters (UU test)	
							c (kPa)	ϕ
1	SPT1	1.2–3.45	19.1	15.8	21.07	CH	32	11
2	SPT2	1.5–6.0	15.8	14.4	9.89	CI	36	12
3	SPT3	1.2–3.9	18.0	15.2	18.25	CH	42	9
4	SPT4	1.1–3.35	18.7	16.0	17.13	CH	30	11
5	SPT5	1.5–6.0	17.0	15.8	7.75	ML	44	17
6	SPT6	1.5–3.4	19.1	17.1	11.65	CL	23	13
7	SPT7	1.5–3.45	17.6	16.3	7.90	CL	26	11
8	SPT8	1.5–5.55	21.0	17.6	19.08	CH	35	9
9	SPT9	1.5–6.9	21.5	18.2	18.38	CH	46	10

internal friction (φ) of the tested samples (i.e. 8 No's) from SPT-1 to SPT-4 and SPT-6 to SPT-9 were found to vary from 23 to 46 kPa and 9° to 13° respectively. In similar lines, the values of total shear strength parameters of SPT-5, cohesion (c) and effective angle of internal friction (φ) were found to 44 kPa and 17° respectively.

3 Stability Analysis of Dumping Yard

The shape of the dumping yard mainly depends on the nature and geography of the area available for dump. Since the available land is almost plain, heaped fill dumping construction method is proposed. The area available for the proposed dumping yard is 1.2 km × 1.0 km. The height of the proposed dump fill is 120 m. The slope of the proposed dumping fill is 23.20. Berm has been provided at every 15 m high intervals. The average slope of the dumping fill with berms is 17.50. The top view and cross section of the proposed dumping yard is shown in Fig. 3. Since dumping yard is to be constructed on clayey soil, the designer has to ensure the internal and global stability of the dump fill. Failure of dumping yard may be due to either inadequate bearing capacity or due to deep seated shear failure. The failure of dumping yard may also take place due to loose dump fill / loose dumped slope upon saturation due to rain. The main objective of the stability analysis is to ensure that the proposed dumping yard does not face any risk due to shear strength parameters of the dumped fill material or drainage issue.

Geo5 software is a tool to provide analytical solutions for various geotechnical applications like design of abutments, cantilever wall, gabion wall, gravity wall and masonry wall. The Geo 5 software is very much useful for design of embankments, stability analysis of normal slopes and steep slopes with soil nailing technique. This software can also be used for settlement calculations and rock slope stability. In the current study stability analysis of the dumping yard has been carried out with GEO 5 (slope stability) software. The stability analysis (verified methodology) has been carried out using classic way, i.e. the stability of dumping yard can be corroborated according to theory of limit or FoS. Bishops method (circular slip surface) is used for analysis of slopes of dumping yard. The foundation soil and overburden dump properties considered for stability analysis are presented in Table 3. Different slope angle of the dump fill has been considered for stability analysis. In the present study, only optimised design cross section (The slip circle with lowest factor of safety) is presented. The results of the stability analysis for different conditions (effect of groundwater table, saturation and earthquake forces) are presented in Table 4. The results of the stability analysis (Table 4) clearly shows that the overburden dump fill slope is stable in all conditions except under saturated condition. Results of the stability analysis indicated that proper drainage arrangements are required for entire slope and top of the dump yard so that the rainwater can be disposed of immediately without saturating the slope.

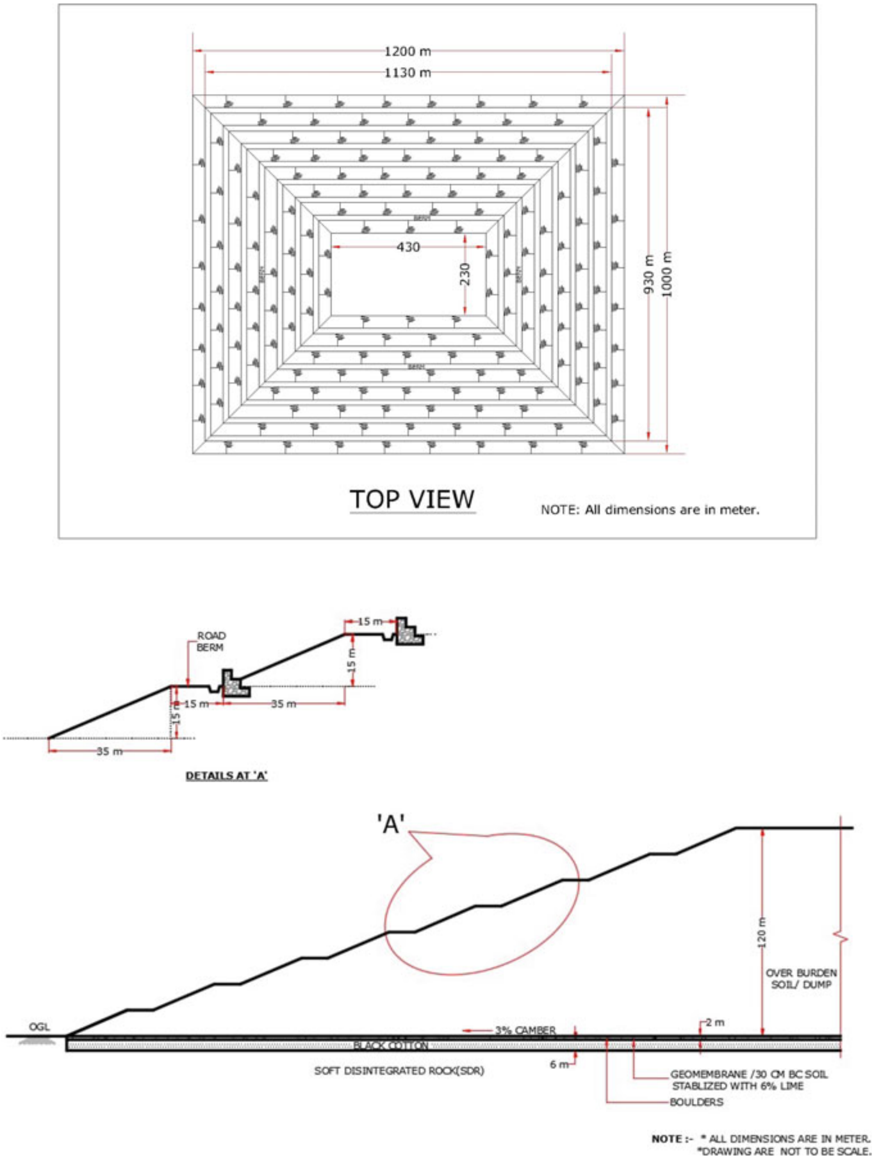


Fig. 3 Top view and cross section of the proposed dumping yard

4 Methodology for Construction of 120 m High Dumping Yard

Before dumping yard construction, it is proposed to first remove/excavate approximately 2 m of top soil. Top 20 cm soil should be stacked separately for dump yard

Table 3 Material properties considered for stability analysis

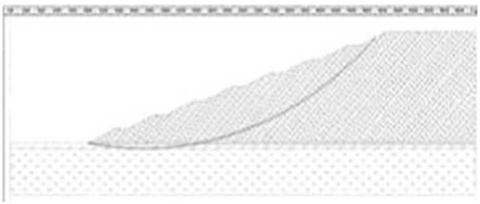
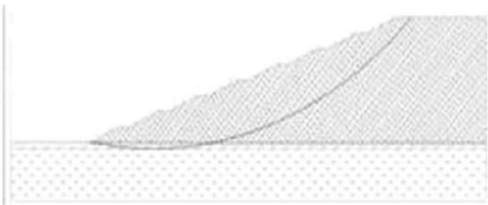
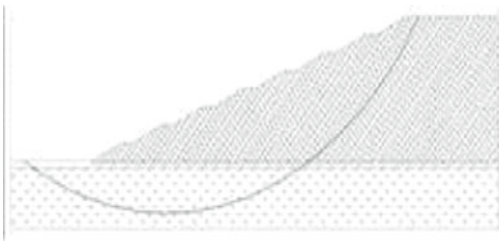
	γ_b (kN/m^3)	c (kPa)	φ
Soft disintegrated rock	19	40	20°
Clayey soil	18	35	9°
Boulders	19	0	32°
Overburden (OB) fill	18	15	25°

reclamation. Remaining 180 cm soil also stacked separately. This soil will also be used as a soil cover for the slope of dumping yard for each stage. After removal of top soil, the soil should be properly cambered for drainage purpose (Fig. 3). The base soil should be properly compacted up to 95% of maximum dry density with pneumatic roller/ sheep foot roller. 25 mm thick sand bedding layer should be spread evenly over the foundation soil to serve as cushion for geomembrane laying and this sand layer should be sprinkled with water and rolled. Geomembrane should be laid over the compacted ground. The geomembrane layer would act as separator between filled soil and Foundation soil. The geomembrane would act as an impermeable sheet and helps in preventing water seeps into foundation soil. The specification of geomembrane should satisfy according to IRC [16].

Over the geomembrane, a 10 cm sand and 190 cm stone/boulder soling should be provided. This will act as a foundation for proposed overburdening dumping fill. Construction of the new dumping yard should be taken up layer wise above the prepared base. In general the waste mine materials usually back dumped in the dumping yard with end tipping method. After dumping the waste mine material, it is generally levelled with a grader. In general the layer is in a very loose condition and these layered materials usually compacted through dumpers while transporting the dumping material (Natural compaction). Some compaction will also take place in due course of time due to further movement of vehicles. At every 15 m, interval height berm should be provided. This berm will be useful for stability of an embankment, drainage can be provided on berm and also can be used as a road for transporting the overburden dump fill. In general, overburden dump fill slopes remain denuded. Hence, the side slopes are very much prone for erosion due to rainfall and wind. The embankment side slopes need protection against erosion. The Gabion toe wall plays an important role in reducing the embankment erosion. The erosion control measures should be applied up to top of the embankment. To ensure that gabion toe wall does not bulge / gets displaced during embankment construction, it is suggested that gabion toe wall construction can be taken up subsequently after embankment construction by suitably trimming the compacted embankment and using a plate compactor. Non-woven polymeric geotextile should be placed all along behind the gabion toe wall.

After constructing the 120 m high embankment (overburden dump fill), the embankment side slopes should be properly protected by providing 300–400 mm (200 mm thick soil cover + 150–200 mm high geocell filled up with soil) thick layer of soil cover (use already excavated and stacked soil for this purpose). This technique helps not only in case of erosion due to run-off water but also in case of wind

Table 4 Stability analysis of proposed dumping fill

S. No		FoS	Remarks
1		1.54	The Dump fill is in dry condition and Water table far below the ground level
2		1.53	The Dump fill is in dry condition and Water table is at ground level
3		0.96	The Dump fill is in saturation condition
4		1.53	The Dump fill is in dry condition and Water table is at ground level
5		1.11 (with earthquake factors)	The dump fill is in partially saturated condition

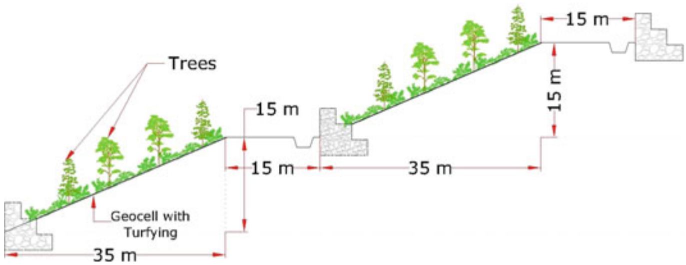


Fig. 4 Embankment slope protected with gabion, drainage, soil cover with geocell with turfing and plantation

erosion. Side slopes of embankment covered with geocell filled up with soil suitable for turfing and tree plantation. Local grass/creepers and plants can be selected based on the expert opinion of agricultural scientist. Figure 4 presents the embankment slide slopes protected with gabion, drain, geocell with turfing and trees.

5 Conclusions

The SCCL is proposed to construct a 120 m high IKOCP dumping yard. The proposed dumping yard has been designed based on the field investigation and stability analysis. The conclusions are drawn from the present study as follows.

- The slope angle of the dumping yard should be less than or equal to angle of repose of overburden fill material.
- The stability of dumping yard is safe in all conditions except under full saturation condition. To avoid full saturation of dumping yard due to rains, longitudinal and transverse (Garland) drains should be provided all along the dumping yard.
- Since the foundation soil is weak (clayey soil), before laying the next layer of fill, the overburden dump fill should be dumped and spread uniformly over the entire proposed area.
- To prevent the rill and gully erosion against wind and rain, the side slopes of the dumping yard should be protected with gabion, drainage, soil cover with geocell with turfing and plantation.
- Since the height of the dumping yard is too high (120 m) and back dumping the overburden fill with end tipping method, the dumping yard should be properly monitored with settlement gauges, piezometers and inclinometers.

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