Landfill Design for Reclamation of Şırnak Coal Mine Dumps: Shalefill Stability and Risk Assessment

Yıldırım I. Tosun, Halim Cevizci, Hakan Ceylan

Abstract—By GEO5 FEM program with four rockfill slope modeling and stability analysis was performed for S1, S2, S3 and S4 slopes where landslides of the shalefills were limited. Effective angle of internal friction (φ′°) 17°-22.5°, the effective cohesion (c′) from 0.5 to 1.8 kPa, saturated unit weight 1.78-2.43 g/cm², natural unit weight 1.9-2.35 g/cm², dry unit weight 1.97-2.40 g/cm³, the permeability coefficient of 1x10⁻⁴ - 6.5x10⁻⁴ cm/s. In cross-sections of the slope, GEO 5 FEM program possible critical surface tension was examined. Rockfill dump design was made to prevent sliding slopes. Bulk material designated geotechnical properties using also GEO5 programs FEM and stability program via a safety factor determined and calculated according to the values S3 and S4 No. slopes are stable S1 and S2 No. slopes were close to stable state that has been found to be risk. GEO5 programs with limestone rock fill dump through FEM program was found to exhibit stability.

Keywords—Slope stability, GEO5, rockfills, rock stability.

I. INTRODUCTION

By erosion, climate, weathering parameters such as earthquakes, the shear stress of natural slope increases and the shear failure of the soil material occur. Growing urbanization brought on the slopes; housing, trade, creation of social space and the realization of infrastructural activities and the realization of infrastructural activities are risky [1], [2]. In determining the danger of slipping and possible future dynamics and stability analysis of the estimated total stress its ability to provide accurate results. Each year, causing heavy loss of life, property damage they create the millions of pounds in the world as you find landslides in Turkey is one of the most important geotechnical hazards [3], [4]. Developing major landslide in the country in recent years, researchers [5], [6] and by the different methods is explored and geotechnical and seismic design of landfills is a difficult task. Due to the heterogeneity of large bulk material must be made of static and dynamic analysis. Due to the heterogeneity of large bulk material must be made of static and dynamic analysis. In this direction, in the province of Şırnak area south of the city and within 7 km from the center of coal mine waste piles (Fig. 1) is evaluated within the city. Working around 3 km² area and a map of the area made 1/1.000 scale engineering, also the drillings and laboratory geotechnical engineering properties of materials are determined by experiments. No residential units appropriate, at the bottom of streams and ponds nature will save condition steep slope design and geotechnical properties by examining the stability analyzes with different methods GEO5 programs FEM program was carried out by [11], [12]. Within this project, urban use, which will open workspace and environment covering 3 km² area 1/1.000 scale engineering map of field and laboratory studies prepared as a result also the polar coordinate system using a field study with four slopes of the topographic maps have been created.

II. ŞİRNAK PROVINCE EARTHQUAKE GEOLOGY

Southeastern Anatolia Region contains various tectonic structures and stratigraphy, even as geothermal energy reservoir rocks and cap rock features, besides being created in the region fault system and especially tension cracks along the ground to the depths of the waters. The geothermal energy fluid changes the formation. North-south direction across the region with the effect of compression of the earth's crust has been subjected to a stretching east-west direction, and the resulting tension cracks along the asthenosphere have risen from the olivine basaltic magma [10], [11].

Diyarbakır-Şanlıurfa -Mardin Karacadag in the rest of Gaziantep Yavuzeli region and the Cizre have the great basaltic magma to the surface in the region into several phases under flowing lava. Batman's north, as well as reaching the earth by magma intrusions in several places gave rise to hot areas. This situation made by the General Directorate of MTA, is evident in the region's geological maps. Lithostratigraphic units in the study area from older to younger Mardin Volcanic (Upper Miocene), Old Alluvium (Quaternary), New Alluvium (Quaternary) and talus (Quaternary) have been
recognized as volcanic, tuffs, agglomerates consisting of basaltic and andesitic splits made up a large portion of the study area basalt lavas in the study area showed a cropped up. 1st degree earthquake hazardous risk point in the province of Şırnak is in a residential area, but 2 nd degree risk point located in near zones. Due to the land tension cracks, construction defects and deficiencies in the buildings are seen in the province. In this study, reflecting the effects of the earthquake load was taken as 0.2W as safety design parameter. As an example ruins seen in the neighborhood as experienced earthquakes in this region indicates that there is a large risk.

Fig. 1 Satellite Image of Şırnak Coal Mine Dumps 1/5000

III. SOIL GEOTECHNICAL PROPERTIES

A. Field Studies
Şırnak to the south of the city center located on a sloping topography was observed. Field generally formed of claystone and siltstone formations were observed. Germav Şırnak center is known that in the formation. Germav formation, corrosion due weakness quickly eroded; with steep slopes create a topography that is caused to occur locally landslides. Therefore, summarizing the central province of Şırnak, usually because of old landslides sandy, calcareous, clayish, silty resulting from the blending of the units are located on disturbed Germav Formation.

Rubble slope of the creek to the south (Fig. 1) extends to the boundaries of the study area. A Field observation of the Miocene limestones of the talus was determined. Thickness is highly variable. Decrease in the slope of the land where experienced in the province alluvial and coastal and marl shale. This section is generally covered with alluvial predominant and has gray sands. Relatively little outcrops.

When examined in Table II, S1, S2, S3 and S4 No. class into The soil samples taken from the slopes of the masses on the results obtained from the geotechnical testing. The samples taken from different rock fill slopes, uniaxial and triaxial compressive strength tests were performed. Also the samples taken from different rock fill slopes, uniaxial and triaxial compressive strength tests were performed. Also in the area where the drilling of the masses and the presentation of the content is given in Table I. Undisturbed shear tests on samples with the help of the examples belonging to the effective cohesion (c') and effective shear resistance angle (φ°) was found. Cutting box of undisturbed soil samples tested in the TS 1901. Also plastic and liquid limits of the results obtained in experiments for each sample are given in Table I. S1 and S2 No. slope of the masses that occur in the ground is not plastic. S3 and S4 No. evaluate the masses of the same occurred with the ground slope was determined to be less plastic.

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Shalefill</th>
<th>Fine Shalefill</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
</tr>
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<tbody>
<tr>
<td>Level(m)</td>
<td>800</td>
<td>850</td>
<td>925</td>
<td>921</td>
<td>933</td>
<td>927</td>
</tr>
<tr>
<td>Wopt(%)</td>
<td>15.90</td>
<td>13.70</td>
<td>10.80</td>
<td>11.40</td>
<td>11.40</td>
<td>11.40</td>
</tr>
<tr>
<td>c'(kpa)</td>
<td>52</td>
<td>88</td>
<td>0.52</td>
<td>0.59</td>
<td>0.63</td>
<td>0.55</td>
</tr>
<tr>
<td>φ°</td>
<td>24.2</td>
<td>22.5</td>
<td>32.50</td>
<td>22.50</td>
<td>21.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Ls(%)</td>
<td>11.8 Mpa 6</td>
<td>9.6 Mpa 6</td>
<td>26</td>
<td>15</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td>Ps(%)</td>
<td>42 RQD</td>
<td>40 RQD</td>
<td>19</td>
<td>11</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>Ip (%)</td>
<td>46 RMR</td>
<td>44 RMR</td>
<td>10</td>
<td>8</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>γs g/cm³</td>
<td>2.70</td>
<td>2.70</td>
<td>2.40</td>
<td>2.50</td>
<td>2.40</td>
<td>2.30</td>
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<tr>
<td>Soil</td>
<td>weak</td>
<td>weak</td>
<td>SP</td>
<td>SP</td>
<td>SP</td>
<td>SP</td>
</tr>
<tr>
<td>γs, g/cm³</td>
<td>1.94</td>
<td>2.14</td>
<td>1.82</td>
<td>1.76</td>
<td>1.90</td>
<td>1.70</td>
</tr>
<tr>
<td>γl, g/cm³</td>
<td>1.94</td>
<td>2.14</td>
<td>1.65</td>
<td>1.6</td>
<td>1.78</td>
<td>1.60</td>
</tr>
<tr>
<td>γw, g/cm³</td>
<td>2.0</td>
<td>2.23</td>
<td>2.02</td>
<td>1.84</td>
<td>2.0</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Soil water content ratio of the clay will be affected significantly. When evaluated according to the percentage of clay in the ground floor of the property shows examples non cohesive or less cohesive.

Which contains the stack of test on samples taken from the one obtained with the bulk density are shown in Table I. For determination of soil types based on grain size, grain size distribution experiments were carried out and the results evaluated in the names and locations of unified soil classification is given in Table I.

In January coal waste piles in the study area (Fig. 1) to the south of the observed surface alluvium new menu are gray marl shale. This section is generally covered with alluvial silty soil while some segments are composed of sandy and clayey zones. By the Special Provinces Administration 35 m up in the drilling of new alluvium is determined to continue [12], [13]. Debris slopes in the study area to the south of the creek, is located. Grain size varies from fine clay and coarse sand. Sorting and grading of unseen debris thickness varies between 10 and 35 cm.

B. Geotechnical Properties
Stack outcropping in the area to determine the geotechnical properties of soils in the experiments Turkish Standards (TS 1900) (TSE 8853), And American Standards (ASTM 3080) is based [14]-[17]. In the area where the drilling of the masses and the presentation of the content is given in Table I. Undisturbed shear tests on samples with the help of the examples belonging to the effective cohesion (c') and effective shear resistance angle (φ°) was found. Cutting box of undisturbed soil samples tested in the TS 1901. Also plastic and liquid limits of the results obtained in experiments for each sample are given in Table I. S1 and S2 No. slope of the masses that occur in the ground is not plastic. S3 and S4 No. evaluate the masses of the same occurred with the ground slope was determined to be less plastic.
TABLE III

PHYSICAL AND MECHANICAL PROPERTIES OF ROCKFILL

<table>
<thead>
<tr>
<th>Specification of rock fill</th>
<th>Shale fill</th>
<th>Marn fill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural unit weight, $\gamma_n$ (kN/m$^3$)</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Saturated unit weight, $\gamma_d$ (kN/m$^3$)</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Cohesion, $c$ (kN/m$^2$)</td>
<td>52</td>
<td>88</td>
</tr>
<tr>
<td>Intern. Friction Angle, $\phi$ (°)</td>
<td>30</td>
<td>34</td>
</tr>
</tbody>
</table>

FEM program to assess the risk of slipping GEO5 programs reviewed in this study is advantageous. FEM GEO5 programs Fellenius in the program, either by the Bishop and Janbu calculation are given. Fellenius method in this method the sliding surface is circular. Floating mass at equal intervals as much as possible is cut into slices [18], [19].

Bishop method, as in all the stability problems is the basis of a start offset and slope limit equilibrium is removed as if assuming equilibrium equations. Bishop, with the total stress and effective stress stability analysis operate. This method of Taylor and brought Fellenius of the methods are older [20], [21]. Method Janbu; this method, whether or not circular can be used for any type of sliding surface [22], [23]. Slope stability analysis in the homogeneous excavation and filling that occurring in the landslide, with non-circular more general types of shifts stability analysis for the inter-slice forces, which takes into consideration is a method. Any slope in the floor, too weak rock mass or rust material properties of the slope along very often varies in if circular slip analysis methods applicability is eliminated [24], [25]. This kind of shift conditions, circular or non- circular slope near the top starting deep in areas along the planar surface is developing ongoing. GEO5 programs possible earthquakes and rock stability groundwater data section in the program in Fig. 2, depending on the rock surface or planar wedge type drift is not formed in particular from 30 to 40 m length was determined.

IV. RESULTS AND DISCUSSION

A. Slope Analysis of S2 and S3 Shale Landfills

The stack S2 hillside after rains made the small size of the movements that have been identified in field studies. No. S2 to develop pile slope is covered with talus and 10 m mesh.

GEO 5 programs entering the ground surface soil parameters were examined and were found to be circular shifts.

Belonging to the limit equilibrium factor of safety of slopes drawn in accordance with different sliding surfaces for the Bishop, with the circular shift method Janbu and Fellenius, FEM program is used diagrams in GEO5 program. Safety factor in limiting the TS 8853 is based. Safety factor of GEO5 FEM was 1.5. $c'$ and $\phi'$ according to the rock fill parameters have been found effective and maximum resistance. When seen in the field of tension cracks are known to occur in movement. In this case, the intrinsic parameters of the sliding surface will appear smaller than those found in laboratories in other words [26], [27]. It is clear that closer to lasting value. In this respect the limits of the confidence coefficient value was 1.5.

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The stack S2 hillside after rains made the small size of the movements that have been identified in field studies. No. S2 to develop pile slope is covered with talus and 10 m mesh.

GEO5 programs were created with the program (Fig. 3 (a)). S2 The top of the stack and the maximum height difference between the heel point 45 m, the slope of the maximum height of 50 m, the slope of the surface tilt angle is 40°.

Drilling carried out by the Special Provincial Administration; according to information obtained from the panhandle talus thickness varies from 11 to 20 m. The fill S2 were the investigation of the slope where the ground water level 35 m was observed at the base S2. The advent of landslides in the slope stability calculations made in $c' = 1.9$ kpa, $\phi' = 22°$, $\gamma_{nat} = 1.97 - 2.27$ g/cm$^3$, and are used to $\gamma_{dry}$. According to $\gamma_{dry}$ and $\gamma_{nat}$ calculated separately on the potential slip surface deformation contour values seen in Fig. 3 (b).

S3 after precipitation in the observations on the slope of a small rupture, leakage occurred was observed. Similarly the slope S3 indicates instability and displacement reached 30mm (Fig. 4).
Fig. 3 (a) S2 section of the study area slopes 10 m mesh topology, (b) Deformation FEM stability analysis GEO5 programs, cut red 30mm unstable displacement

Fig. 4 S3 heel unfilled limestone slopes of the study area section, sensitivity analysis FEM GEO5 programs. Deformation, Red unstable cutting surface

By designing Slope S2 various rubble mound is formed like 2m mesh (Fig. 5) by the GEO 5 FEM program. FEM GEO5 programs groundwater data section in the program depending on the level of the groundwater surface effect and poor stability analysis was conducted by placing in cross section. This 10- m-wide geostationary shale stone fill, depending on the pressure and stress in the critical shear surface prevents slipping. S3 limestone filler 3milık By designing the slope 3m is formed like mesh (Fig. 6). In addition, thin shale and clayey soils were stabilized with fly ash. This limestone filler geostationary 3 m wide, depending on the pressure and the critical shear stress in the surface region is completely prevents slippage. In addition, 1m wide and 10 m high concrete - rock fill out a safety factor values were above 3 (Fig. 7).

Weak adverse effect with the sliding surface as shown in Fig. 8 (a) and a weak surface tension in the design frequency 2 m mesh weave texture is formed. In this design, even with the heel stone fill that provided stability, security coefficient values exceeded the value of 3.

When using a filler to form the slope S3 instabilities deformation displacement are shown in Fig. 8 (b) and displacement m below the maximum possible shift of the substrate 20 has reached 9 mm (Fig. 8 (b)).

S3 slope instabilities will form filler when used in kPa shear stress is shown in Fig. 9, and ranged from 10 to 16 kPa and 16 kPa reached a possible shift in the base.

GEO5 programs FEM program, the excellent stability of the filler in the cross section shown in Fig. 10 the epsilon (x/z) is calculated as a % of substitution. The critical slip displacement occurs at the base of the possible maximum of 0.77% as seen in Fig. 10. Accordingly, around the sides of the small size of the stack is seen that the risk of slipping.
Şırnak located in urban areas close to the border regions of Coal Waste piles. Dumps were separated four units of the slope and slope stability geotechnical properties of soil samples taken from field studies and laboratory experiments have looked at. Risk maps of slope stability and GEO5 FEM programs and stability programs and Rock Slope Stability analysis with high accuracy can be quickly and successfully. Soil-rock contact or mass due to a structural feature such as, in the presence of low levels of planar shear strength is developing planar slip surface in case. This experiment on the ground with the optimum water content and maximum dry unit weight determined and should be used in the calculation of the stability of slopes.

The laboratory tests performed on samples of rocks as a result of the fine and coarse shale fill slopes, respectively, for the value of the cohesion of the 120-180 kN/m², the angle of internal friction 30.5-34.4° were changed between. In the unified soil classification of soils is determined to be plastic. Stability analysis performed in the light of this information, the S4 The slope is stable, S1, S2, and S3 not the slopes are not stable and will be stable with stone fill was concluded.

Şırnak city and surroundings, according to Turkey Earthquake Zone Map is located within the danger zone in the first degree. South East Anatolian Fault Zone in this area was the domain of frequent earthquakes occurred in the region and due to this earthquake consists of some tectonic movements. 0.2 lateral loads in the GEO5 programs passed as this effect and stability is provided in rock fill. However, the application of anchoring the slopes could be made in residential building areas under that of distinct the danger.

Weathering of rocks largely unchanged, the bond between grains leads to weakness and not completely. In the study area weakened by weathering rocks are easily eroded and slope angle of inclination of the slope is changing with height. Dissociation observed in rocks in the study area has a negative impact on the stability problem.

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