Chapter

Anchorage Pile Strengthening of Shale Slopes and Cementing Falling Stone Blocks by Mixture of Melted Waste Plastics/Asphalt and Fly Ash for Slope Stability in Asphaltite Open Pit Mining Site in Avgamasya, Şırnak

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Abstract

The Rock Fallings, Shale Slopes Stability, and Stability Risk Assessment in Şırnak open pit asphaltite mining should be searched in detail and improved in several coal mining sites in Şırnak Province, reaching over 120 m height with 60–65 degree shale slopes, developing major landslide in the open pit Şırnak open pit coal mining. The rock fallings endangered the mining safety in recent years. This research provided stability patterns and cementing method strengthening cracks. The stages of experimentation explored the geo-technical characteristics and geoological formation. Fort his aim, four different open pit mining areas with similar geotechnical conditions, two main strengthening methods, and patterns of researches were developed. Firstly, data on landslides and rock dynamics over explosions were followed, and secondly, as happened commonly in the past, the same geological, geomorphologic, hydrological, climatic conditions were taken. Anchorage pile strengthenıng of slopes and cementing falling stone blocks were performed by mixtures of melted waste plastics/asphalt and fly ash for stability of higher slopes over 120 m height and over 65 degree in asphaltite mining site in Silopi and Avgamasya open pit No.1 mining site in Şırnak were carried out. On the other hand, due to that creep style rock falling from top of slopes, those melted polymer cementing of anchorage bolting and cracks, to eliminate those falling failure types and features, will be advantageous. The unconditional expectations related to this study was also defined for this region, such as the influence of the ground water, rock cracks and slope design, and explosion exchange dynamics leading to landslide. GEO5 software and manual stability analysis showed high risk area for plotting.

Keywords: mining pit, Şırnak asphaltite, active potential landslide, mining, geotechnical stability, slope stability

1. Introduction

Engineering geotechnical properties of surface units were determined by making geological map of Şırnak province and surrounding areas [1–5]. Geological mapping of slopes on large-scale topographic maps was one of the first landslide studies in the region. By determining the engineering properties of the slopes, it was aimed to draw attention to the importance of the area and the geotechnical criterion in the construction of the municipal development plans in the future.

Landslide is the downward slope due to the effects of massive soil masses or rocks on sloping slopes in mountainous areas such as gravity, slope, water, climatic factors, tectonics, weathering [6–9]. The geology of the material can be listed as precipitation, erosion, earthquake, and vegetation deprivation. Limit stress and balance analyses give accurate results in determining the landslide hazard and predicting future landslides [10].

In areas with high danger, landslide and related events will increase proportionally with increasing population density. It is very difficult to eliminate and reduce the risks arising from the processes of these landslides. There is an urgent need to better understand the character of the operation safety in open pit coal mining and to develop more predictive tools for stability.

Processes such as heavy rains, seismic, changes in groundwater level, erosion, climate, weathering, and natural topography are the natural parameters that trigger landslides. These effects increase the shear stress or decrease the shear resistance of the slope material [11]. Another important parameter that triggers landslide is urban activities. Increasing population and creating new living spaces forced people to settle on the slopes that present geological danger. The realization of equipment uses such as installing, practice, the creation of safe areas, and the realization of stress structure activities brought on by the excavation developed on the slopes can disrupt stability and create human activities and explosions that trigger landslides.

Especially in developing countries, the land in mountainous areas is not used in accordance with the topology, and wrong land use increases the probability of landslide development. Sustainability cannot be achieved in terms of physical environment, change and efficiency of landslide risk areas in open pit mining sites, and operation safety.

Important landslides developed in open pit coal mining of the country in recent years are determined based on ground conditions. The stability of working area was managed with different methods such as geotechnical characters and geological formations, precautionary measurements, and the processes determined. Researchers have two basic theories for areas with similar geotechnical conditions [12–30]. Firstly, landslides are formed in the same geological, geomorphologic, hydrogeological, climatic conditions as in the past. Regarding the past phenomenon, the stability studies were carried out. Another is that the types and properties of landslides will be the same with other open pits. Therefore, knowing the mechanism and properties of past landslides is important basic information to evaluate landslides that may develop in the future, neighboring regions, or geotechnical similar areas. Geological and geotechnical analyzes of the slopes should be carried out in order to minimize the economic and social losses and casualties caused by landslides. In this direction, within the coal mining area of Şırnak Avgamasya and Silopi, open pit mining was carrying high landslide or rock falling risk (**Figure 1a**).

The geotechnical properties of the slopes where landslides occur in the districts that are 0.2–0.4 km from the south of the city and the center are analyzed, and the stability analyses were carried out with different methods using the GEO5 program. Within the scope of this project, a 1/5.000 scale engineering geology map covering 0.07 km^2 of the study area and its surroundings that will be opened to urban use has been prepared as a

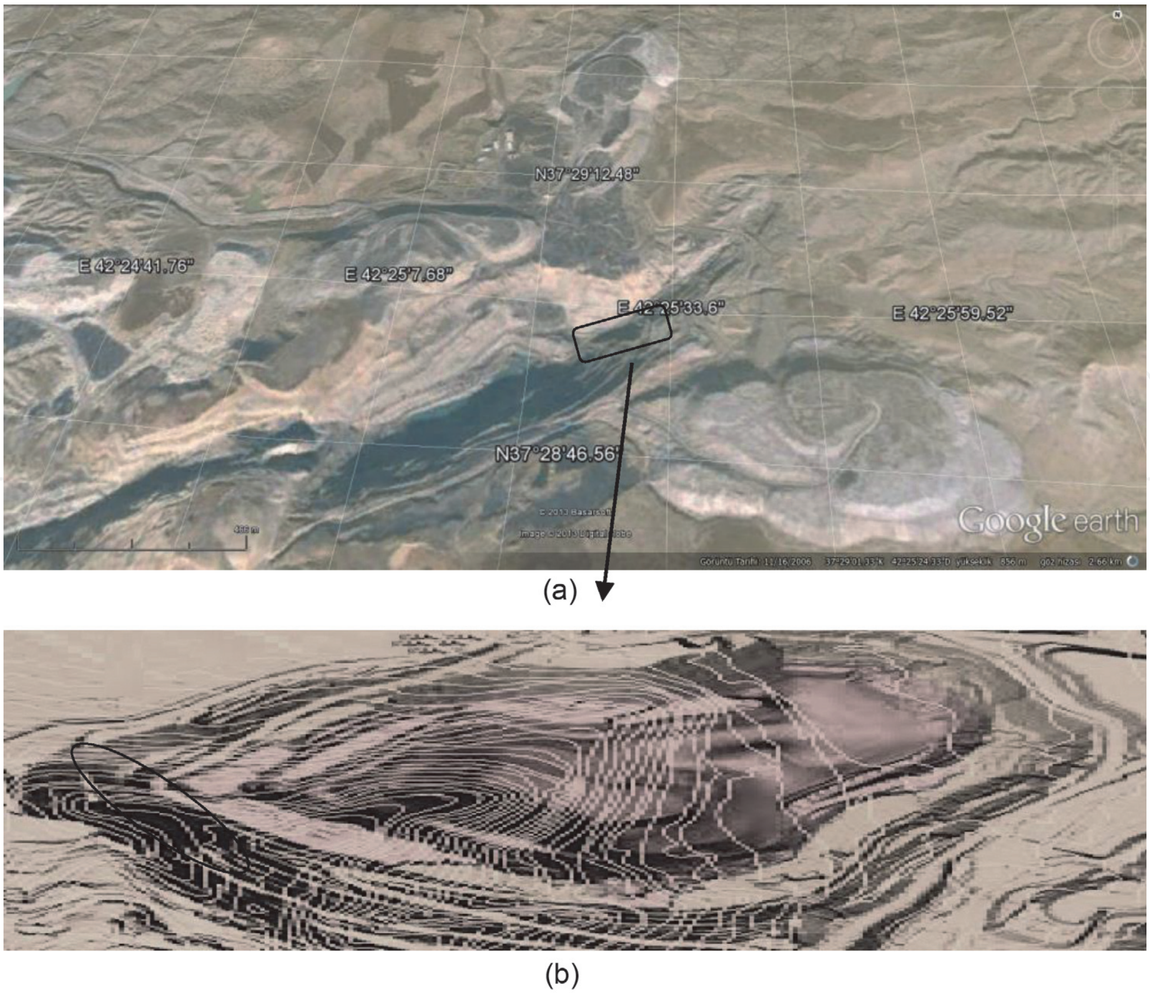

Figure 1.
(a and b) Satellite and contour topography of Avgamasya No.1 Pit Şırnak asphaltite coal mine site and survey area 1/18000 and 1/5000.

result of field and laboratory studies, and a topographic map has been created for all four hills by using the polar coordinate system. The high risk of rock sliding or falling damaging the asphaltite coal production occurred at the local open mining site 1 in Avgamasya seen as shown in **Figure 1b**. Black area was coal extracting area.

2. The coal geology in Avgamasya, Şırnak

Due to its tectonic structure and stratigraphy in the Southeastern Anatolia region, besides having reservoir rock and cover rock properties required for hydrological conditions, the water going down to the depths of the ground along the stretch cracks in the region are in a position to provide the necessary fluid for open pit asphaltite mining [31]. The crust of the earth was subjected to a stretching in the east-west direction with the effect of compression in the north-south direction throughout the region, and olivine basaltic magma rose from the asthenosphere along the stretch cracks formed.

Basaltic magma, which reaches to the surface in the Karacadağ region between Diyarbakır-Şanlıurfa-Mardin, Gaziantep Yavuzeli region, and İdil-Cizre regions, flowed in several phases and left large areas under lava flows. Magma, which does not reach the earth, as in the north of Batman, created hot areas by making intrusions in several places. This situation in Şırnak is not clearly seen in the geological map of the region made by MTA General Directorate. The four lithostratigraphic units in the study area were distinguished from late period time age as Mardin

Vulcanite (Upper Miocene) [30], Old Alluvium (Quaternary), New Alluvium (Quaternary), and Slope Rubble (Quaternary). Consisting of vulcanite, tuff, agglomerate and andesitic basaltic lava, syenitic rocks, which make up a large part of the study area, it shows as much shale and porous rock formations and slopes as occurred in the studied area chosen.

In recent years, both the opening of our university in our city and the migration movement from rural to provinces have also affected the coal economy in Şırnak. Open pit mining excavation and asphaltite production increased in different excavated pits in the area. A total of 500,000 asphaltite excavation by Asphaltite open pit mining with 20 separate pits continued to increase rapidly in Şırnak. Equipment and safety demands have also increased due to excessive extraction. This increase in demand caused people who are not competent in excavating in open pit mining production to enter the hauling, the control mechanism of dumping ability, modeling slopes to control the intensive stability, and areas that are not included in the development plan that are rapidly foreseen to mining development and safety. A vast majority of the excavatings in the Avgamasya open pit No. 1, 2, 3, 4 were excavated without adequate ground research. In the asphaltite mining of Şırnak, there were generally adjacent open pits in Silopi, Uludere. It is believed that such new open pits in Şırnak have been developed due to the neighboring hard condition of rock cracks, rock fallings, landslides, and sometimes the existing collapsed pits (or structural damage caused by the rotation of the equipment) or hydrological ground problems. Finally, Şırnak Avgamasya No. 2 landslide caused 8 workers' death, closing the excavation work. For these reasons, the investigation of the new buildings to be built in our province and the ground conditions on the basis of regional and parcels of new areas to be developed has become essential [18, 19]. The unconditional expectations related to this study were also defined for this region such as the influence of the ground water, rock cracks and slope design, and explosion exchange dynamics leading to landslide. GEO5 software and manual stability analysis showed high risk area for plotting (**Figure 2**).

Another issue for the province of Şırnak is the causes of the damages that may occur in possible explosions and earthquake shock waves caused by human conditions which are due to the engineering errors as well as the lack of control mechanism and construction defects in the excavating process. Şırnak Avgamasya open pit No. 1 mining site is located in the 2nd degree earthquake zone and these shortcomings mentioned above are also seen in our city. As seen in **Figure 3**, the risk of slope stability risk in explosions and excavation near earthquake district of 1

Figure 2.
Avgamasya No. 1 pit Şırnak asphaltite coal mine site and survey area.

Figure 3.
North face of Avgamasya No. 1 pit Şırnak asphaltite coal mine site and survey area.

degree in Uludere Ortabağ districts. Cizre and Merkez were areas of 2 degree risk. The studies considered to take precautions for steep slopes avoid those as below:

- steep slope structures over 60°;
- earthquake resistant hollow-type structures;
- high slope type pits, excavating without basement control in real sense; and
- slope models designed without paying attention to hydrologic conditions and ground conditions did not escape attention.

Ground movements that may occur on a regional and/or 5–10 m basis have been observed in many irregular shale facing, high crack risk areas as seen in **Figure 4**.

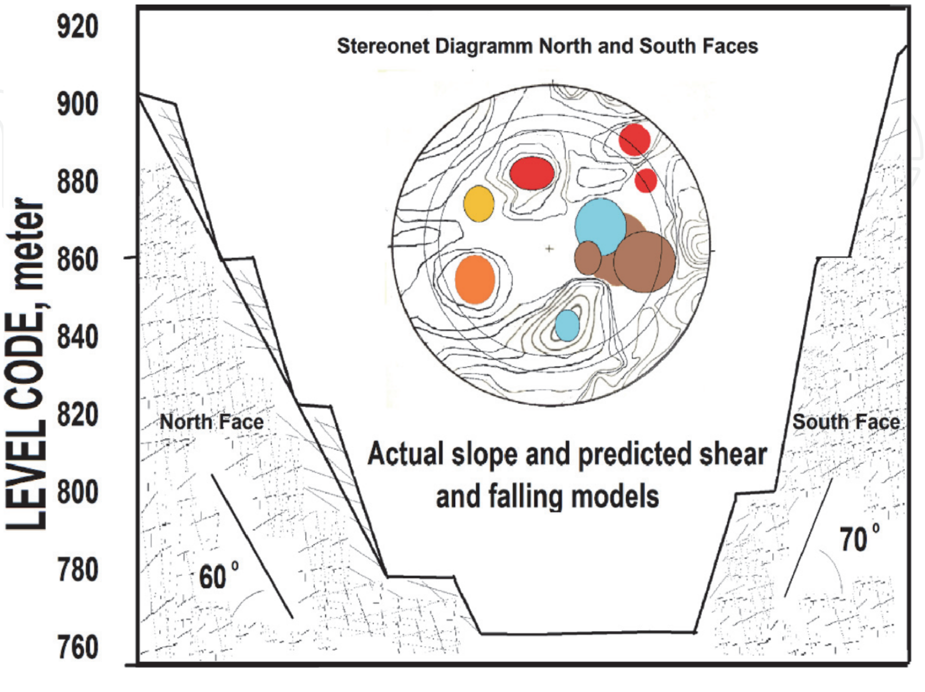

Figure 4.
North and south steep slope faces of Avgamasya No. 1 pit of Şırnak asphaltite coal mine site and survey area.

3. Geotechnical properties of slopes and modeling

3.1 Field studies

It is observed that the city center of Şırnak is located on a topography inclined to the south. Formations generally are composed of claystone and siltstone in the field.

It was observed and it is known that the center of Sirnak province is in Germav Formation. Germav Formation causes rapid formation of landslides as it forms a high slope topography by rapidly eroding due to its wear resistance. Therefore, in summary, Şırnak city center is located on the anchored Germav Formation, which is a mixture of sandy, carbonated, clayey, and silty units due to old landslides. Slope debris extends from the south of the stream (**Figure 2**) to the boundary of the working area. It has been determined with the field observations that the slope debris is composed of myocene limestones. Their thickness is extremely variable. They outcrop relatively less in areas where slope inclination decreases.

The surface of new alluvial deposits starting from city center to the south of Avgamasya open pit 1 (**Figure 3**) in the study area is gray marl shale. This part is generally covered with silty soil, and some parts of it consist of sandy and clayey zones. It has been determined that the new alluvium continues in the drilling up to 35 m by the Special Provincial Administration [32]. Slope Rubble is located south of the Stream in the study area.

Grain sizes range from fine clay to coarse sand. The thickness of the rubble, which does not show any grading and grading, varies between 10 and 35 cm. The active and potential landslide areas observed in the slope debris have been studied in detail.

3.2 Geotechnical properties

American Standards (ASTM 3080) were taken as a basis in the experiments carried out to determine the geotechnical properties of the surfaces surfaced in landslide risk areas. In the landslide risk areas of the study, undisturbed and lump rock samples were taken from the ground parts of the slope face. In experiments on the lines shown in **Figure 5**, the slope unit weight in wedge style and circle shape were considered in analysis with manual and GEO5 software and safety consistency limits were obtained.

The slope model construction plan is shown in **Figure 6**. The anchorage improved stability safety factors for steep sliding slopes in 20 m height excessive to 30 m. Wire mesh hanged top of slopes were avoiding rock falling of highly cracked shale block stones at 3–5 m size. The pile anchorage was designed and practiced for

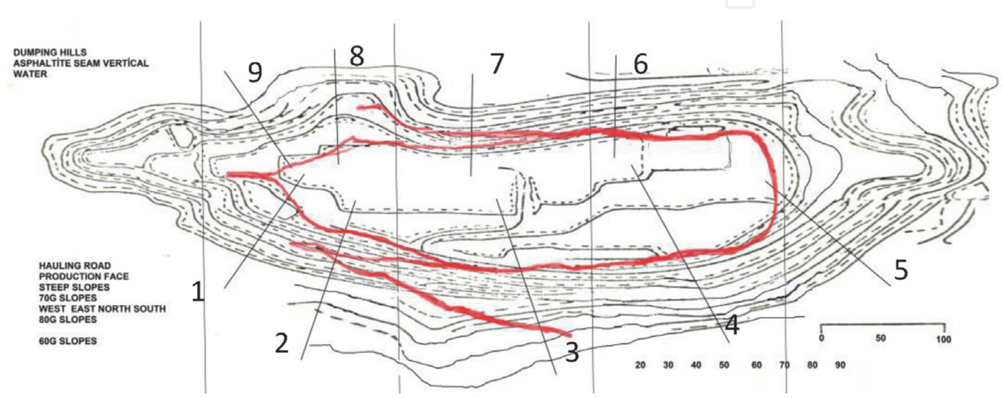

Figure 5.
North and south steep slope faces of Avgamasya No. 1 pit of Şırnak asphaltite coal mine site and survey area with anchorage pattern.

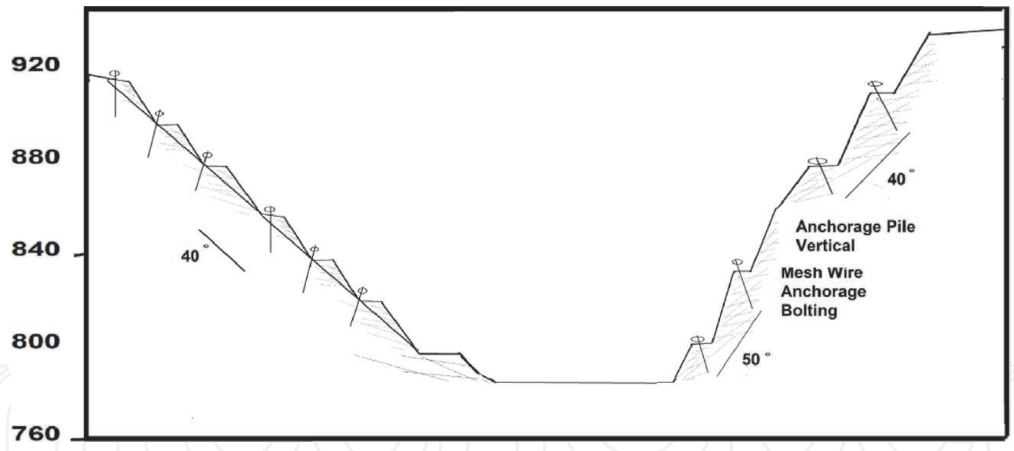

Figure 6.
North and south steep slope faces of Avgamasya No. 1 pit of Şırnak asphaltite coal mine site and survey area with anchorage pattern.

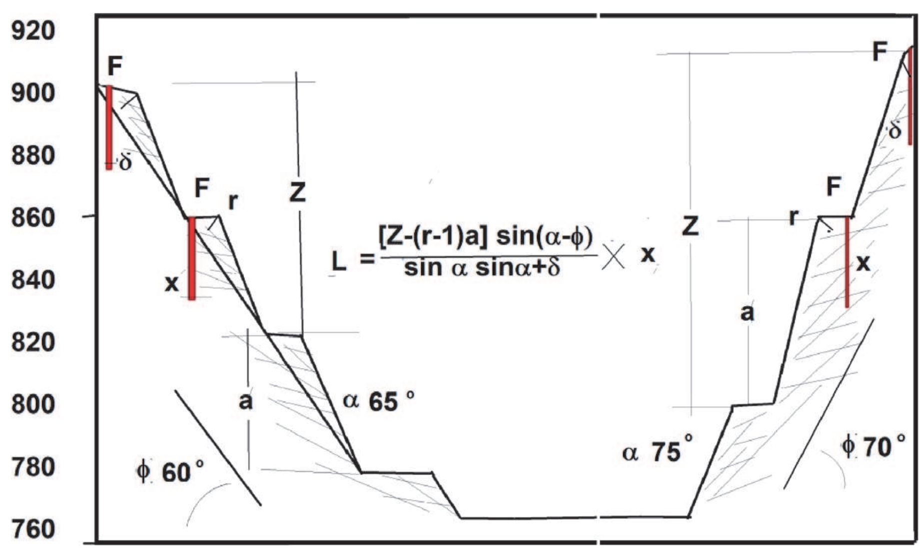

Figure 7.
North and south steep slope faces of Avgamasya No. 1 pit of Şırnak asphaltite coal mine site and survey area with anchorage pile pattern.

hauling road slopes control and stability at the constructed near deep of slopes bottom line as shown in **Figure 7**.

The uniaxial compressive test point load tests, RQD values, and Mohr-Coulomb criteria diagrammed were determined regarding ASTM standards; effective cohesion (c‘) and effective shear resistance friction angle (ϕ°)’ of the rock samples were given in **Tables 1** and **2** on the standard rock samples of 50 mm cubic forms with the help of ELE press equipment [23–25].

Undisturbed rock samples used in the point load experiment were classified according to ASTM standards and determined as cracked, altered ground. Rock samples show nonplastic character and there are also coarse-sized gravel.

In addition, during the making of these experiments, the unit volume weight, the amount of compression, and the void ratio were determined.

The results obtained in plastic and liquid limit tests are given in **Table 1** for each sample. According to the ground classification in North district, the slope samples in the landslide N1 are in the less plastic shale and not plastic group, whereas in the region containing the landslide hazard N2 and N3, it is determined that there is less plastic.

Rock formations	Thickness (m)	RQD (%)	c′ (kPa)	φ′	P1 (MPa)	I1 (MPa; 50 mm)	Shear strength (mm/s)	γsat n (g/cm^3)	γdry (g/cm^3)
S1	25	25.9	3700	22	22.0	1.4	22	2.92	2.58
S2	74	42.9	3300	28	15.0	1.8	13	2.92	2.57
S3	25	40.8	2300	32	26.0	1.7	14	2.9	2.62
N1	47	25.9	2700	18	38.0	1.0	25	2.92	2.61
N2	55	35.4	4700	17	33.0	2.3	12	2.8	2.68
N3	46	33.9	4100	14	36.0	2.2	12	2.8	2.68

Table 1.
Results from geotechnical tests on samples taken from landslide slopes.

Rock no	S1	S2	S3	N1	N2	N3
γ_{sat} max (g/cm^3)	2.98	2.75	2.77	2.98	2.75	2,77
w_{opt} (%)	15.9	11.9	11.0	12.3	3.8	3,3
Permeability (k) (cm/s)	5.3*10–4	3.0*10–5	6*10–5	1.3*10–4	3.3*10–6	5.2*10–6

Table 2.
Proctor of ground samples and permeability test results.

The results obtained from the geotechnical tests carried out on the samples taken from the slopes forming the landslide threat are given in **Tables 1** and **2**.

4. Results and discussions

The water content on the ground will be significantly affected by the clay content. When evaluated according to the percentage of clay in the floor, the floor samples show a non-cohesion or low cohesion feature.

The grain volume weights obtained by the experiments done on the samples taken from the landslide sites are shown in **Table 1**. In order to determine the soil types according to the grain size, grain distribution experiment has been carried out and the results and names in the combined soil classification are given in **Table 1**.

In order to determine the permeability of the ground, a fixed level permeability test instrument was used. The degree of permeability of the ground was determined by evaluating the results of the experiment (**Table 2**). When **Table 2** is examined, it is seen that the slopes S1, S2, and S3 fall under the permeable ground class.

The γ_k and w_{opt} values obtained as a result of Proctor experiments on soil samples taken from landslide areas are given in **Table 2**. With this experiment, optimum water content on the ground and maximum dry unit volume weight are determined and used for stability calculations of the slopes. Compaction parameters do not affect the stability of a natural slope, because these parameters are the parameters of the ground compacted in the desired way. In artificial slopes, compression parameters are used directly. If there is a landslide danger in a natural slope, in case of compression, the stabilization analyses are compared using these parameters. In the precautions to be taken against landslide danger, compacted filling can be made in front of the slope or bench slope can be made in the slope. At the same time, the natural ground is dug up and compacted according to the recompression parameters. In this case, parameters of the compacted soil can be used in stability analysis.

In order to determine the slip resistance parameters of samples taken from different points of four separate slopes, a cutting box experiment was carried out. After the experiments, c′ and ϕ′ values were found. The stability analyses were carried out by the model constructed and practiced in the field as shown in **Figures 8** and **9**.

The manual weight chart method was so efficient and useful in slide pattern analysis in the area as shown in **Figure 9**. The sliding surface is circular half cylindrical. The sliding mass is divided into slices as equally as possible [33].

The safety coefficient values of the landslides were calculated according to Fellenius, Bishop, and Jambu [1, 34].

Fellenius method: if the forces between slices are considered to be in the same direction but opposite and equal to each other, they are not taken into account in the analysis. In the back, only the slice weight, ground reaction, cohesion, friction resistance, and leakage forces, if any, are in balance, without drainage on partially water-saturated floors.

The rupture envelope, which is determined by the strength's test under conditions, does not parallel the normal tension axis after a point, and the ground behaves both cohesively and internally. Total tension analysis method can be applied to cover this condition and to analyze stability by sliding mass divided into a certain number of vertical slices [12, 35–37]. **Bishop method**: in this method, as in all

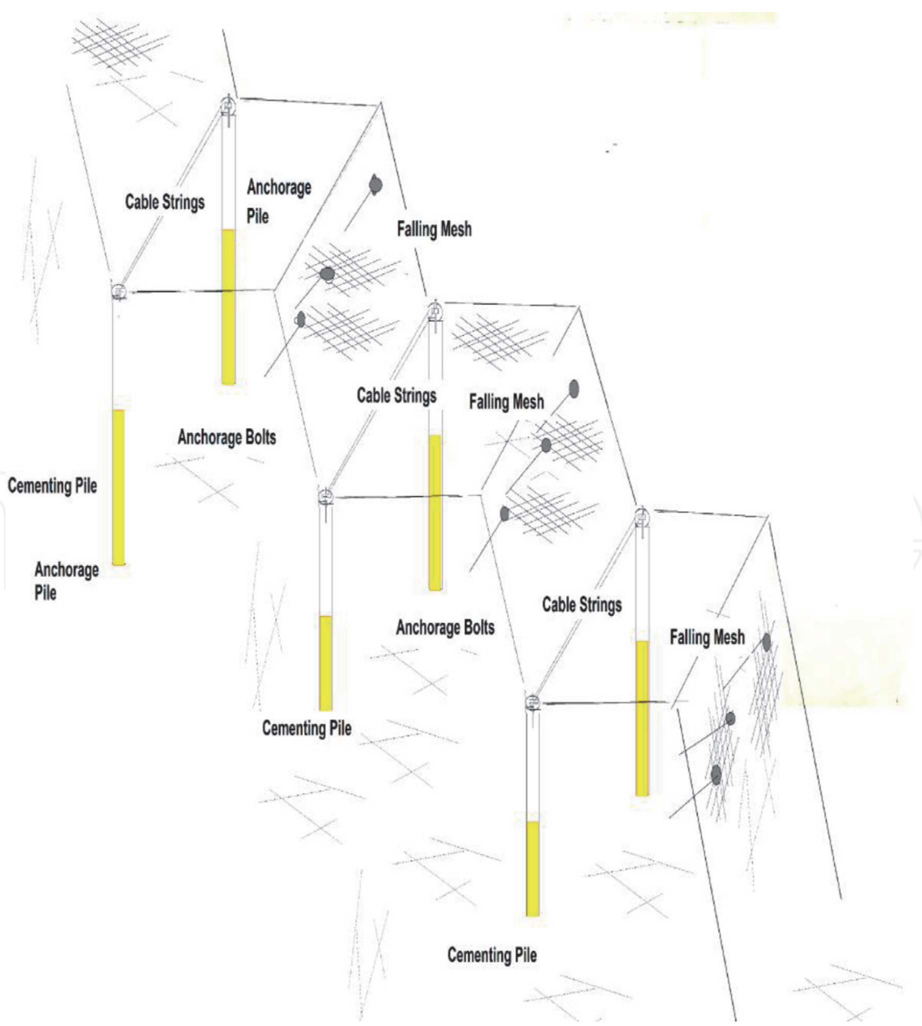

Figure 8.
North and south steep slope faces of Avgamasya No.1 pit of Şırnak asphaltite coal mine site and survey area with anchorage pile pattern and PE melting paste filling to cracks.

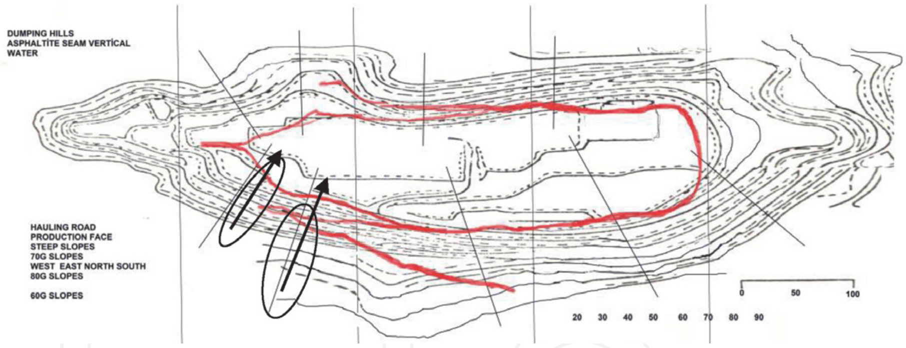

Figure 9.
Sliding shale areas contour topography of Şırnak Avgamasya open pit No.1 mining area and survey area 1/5000.

stability problems, the initial shift is taken as post-equilibrium equations are taken out as if the slope is in the limit equilibrium. Bishop performed analysis with effective stresses instead of total stress. This method is more advanced than the methods brought by Taylor and Fellenius [28, 29]. **Janbu method**: this method can be used for all types of sliding surfaces, whether circular or not. In the slope stability analysis, it is a method that takes into account the inter-slice forces for the stability analysis of the more general types of noncircular shifts with the circular shifts occurring in the homogeneous split and fillings [38].

If the properties of the ground, very weak rock mass or rust material in any slope vary frequently throughout the slope, also the applicability of circular shear analysis methods disappears due to a structural feature such as ground-rock touch or in the presence of low shear strength planar levels in the mass [12, 13, 36, 37]. Shifts under such conditions: it develops along surfaces that start circularly in noncircular or near slope-top areas and continue in planar depths [14–17]. It is a method used to examine the stability of slopes, where instabilities develop or may develop along such sliding surfaces.

4.1 Model slopes and landslide analysis

In order to evaluate geological and landslide data, 1/1000 scale topographic maps of the slopes were prepared by field studies. Polar coordinate system was used in map production and Topcon GTS 702 electronic device was used. The heights are given according to the triangulation point on the 1200 m high hill. Topographic maps prepared for 4 slopes in the study area are given in **Figure 1**. In these 4 slopes, active and potential areas in terms of stability have been distinguished as a result of the surface studies on landslide.

According to the studies conducted, the regions where landslide is developed and the areas where relative movements are observed have been determined as active landslide area. Relative movements are determined by using the stress cracks on the surface. Potential landslide areas, on the other hand, correspond to areas where there are stress cracks around these active sites, but relative movements are not currently observed. In the study area, geological sections were prepared by marking the geological outcrops on topographic sections taken from 4 different slopes.

The safety coefficients of the slopes have been used with Bishop, Janbu, and Fellenius methods and circular slip diagrams GEO5 program for different slip surfaces [39, 40]. It is taken as 1.3 in ASTM standard in the limitations of safety coefficients. In laboratory experiments, c′ and φ′ were found according to the effective and maximum resistance parameters. It is known that movements occur in the stretch cracks in the field over time. In this case, the internal parameters on the sliding surfaces are more than those in the laboratories. It will be small, in other words, it will be closer to permanent values. In this respect, the value of 1.35 was taken as the limit security coefficient.

4.2 Slope S1 landslide risk analysis in Şırnak Avgamasya open pit No.1

According to the combined ground classification (USCS) located on the skirts of Şirnak Avgamasya open pit No.1 ground, movements in the area S1 consisting of shale group stones continued as high erosion creep with steep slope. Tectonic events occurring in the region have also triggered movements and continued to this day. Nowadays, there are small-sized movements on the slope after the rains.

The discontinuous cracks were studied by cable extensometers weighted and observed as cm changes by daily periods in the control work. The slopes where landslide risk S1 is covered with pile anchorage and mesh slope stabilization by melted waste PE pressed (**Figures 8** and **10**). The maximum elevation difference between the top and heel point of the landslide S1 is 72 m, the maximum height of the slope is 80 m, and the slope angle of the slope is 58°.

In the observations made on this slope during the field studies, it was observed that it took the material that occurred in the stream and that small breaks and flows occurred after the precipitation. The geological map and landslide cross section and the surfaces where the calculations are made are given in **Figure 10**.

4.3 Rock tests and crack stabilization by melted waste PE

Mineralogical compositions of the samples were determined by means of standard chemical Ca, Mg, and silica analyzes. The samples were first brought to dimensions between 40 mm and 10 mm in jaw crusher and were homogenized by milling to 0.1 mm. Powder samples are thawed and burned with HF in platinum crucible for silica content. Chemical composition of the rocks provided in the vicinity of Şirnak province in the experiments is given in **Table 3**. The amount of silica in the marly and marly limestone was reduced.

Prior to the preparation of the melting mixture by fly ash, micropictures showed the macropores in which melted PE penetrates into the pores and makes the pores stick easily to stabilize cracks as shown under the microscope pictures (**Figure 11**).

Şirnak limestone, Midyat limestone, Şirnak marl, and marly shale were sized at 50–70 mm cubic blocks. The blocks were compressed with ELE press under 30 kN compression The blocks were crushed in test. The test results were given in

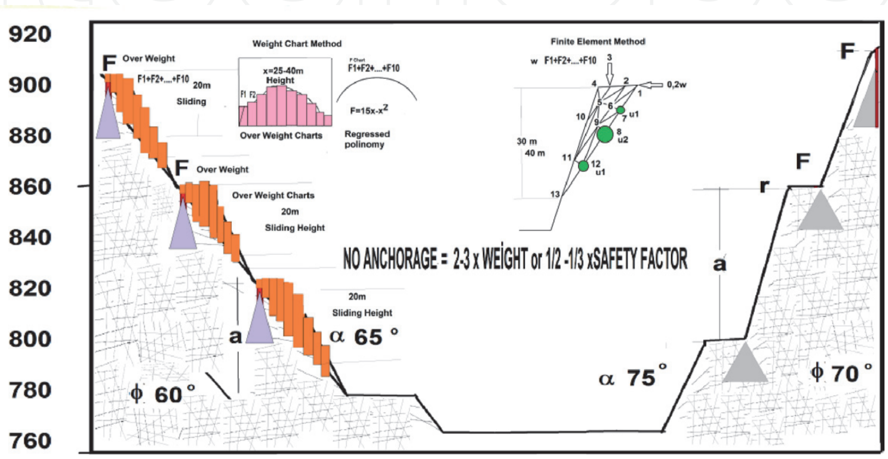

Figure 10.
Sliding shale landslide risk cross section with slope topography of Şırnak Avgamasya open pit No.1 mining, models for stability analysis.

%Component	Sırnak marly shale stone	Şırnak Marl	Şırnak porous limestone	Şırnak shale
SiO_2	9.42	24.14	2.12	48.53
Al_2O_3	6.53	12.61	1.71	24.61
Fe_2O_3	4.48	7.34	0.58	7.59
CaO	39.23	29.18	45.22	9.48
MgO	2.28	4.68	7.41	3.28
K_2O	0.53	3.32	0.40	2.51
Na_2O	0.24	1.11	0.21	0.35
Ignition loss	26.11	21.43	48.04	3.09
SO_3	0.21	0.20	0.02	0.32

Table 3.
The chemical analysis of rock specimens of Şırnak asphaltite Avgamasya open pit mine No.1 site limestone, marly shale, and shale.

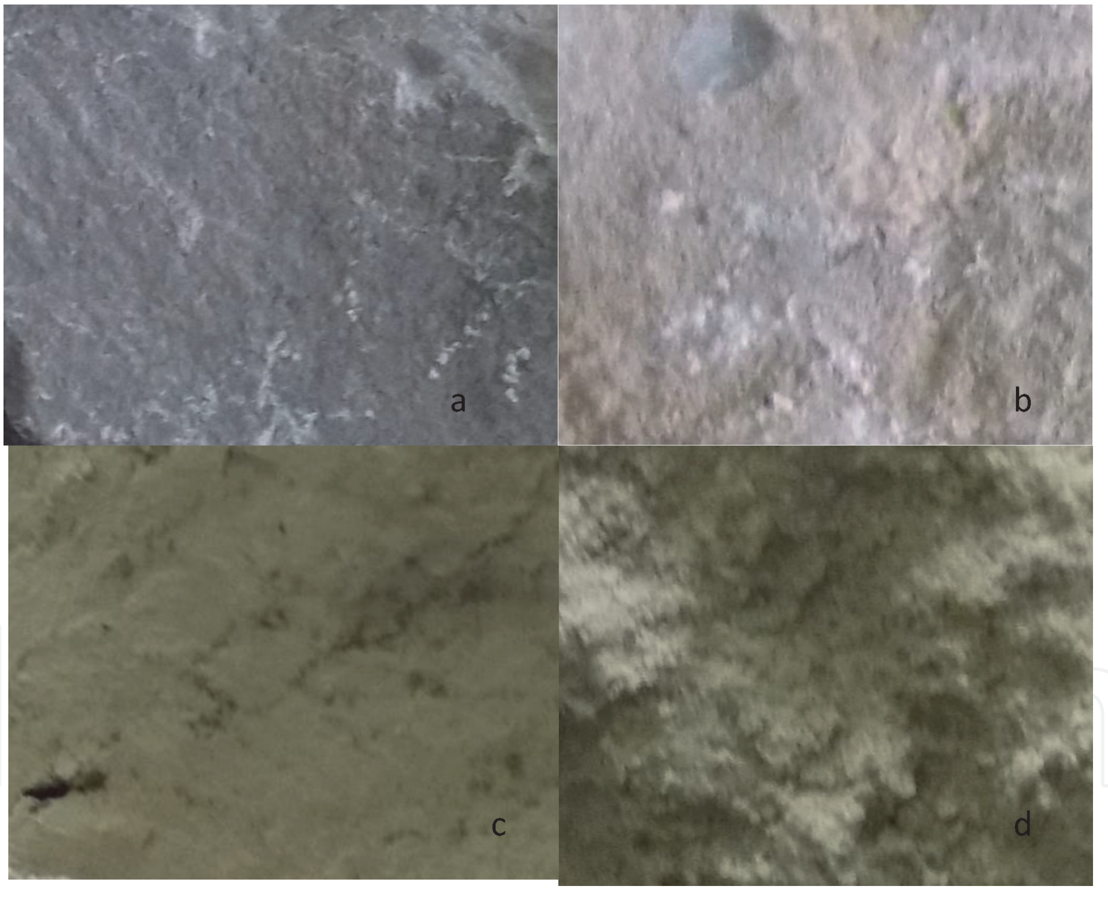

Figure 11.
(a) Shale, (b) marly shale, (c) Şırnak porous limestone, and (d) the Şırnak-altered porous limestone.

Figures 12 and **13** within the limit indentation pattern values charted, as given in **Table 3** (**Figures 14–16**).

4.4 Point loading and compressive strength tests of rocks

The test samples were produced as 5 × 5 × 5 cm blocks and 10 samples were determined to be with 95% accuracy rate by prestigious ELE brand test equipment. The results are shown in **Figures 6** and 7.

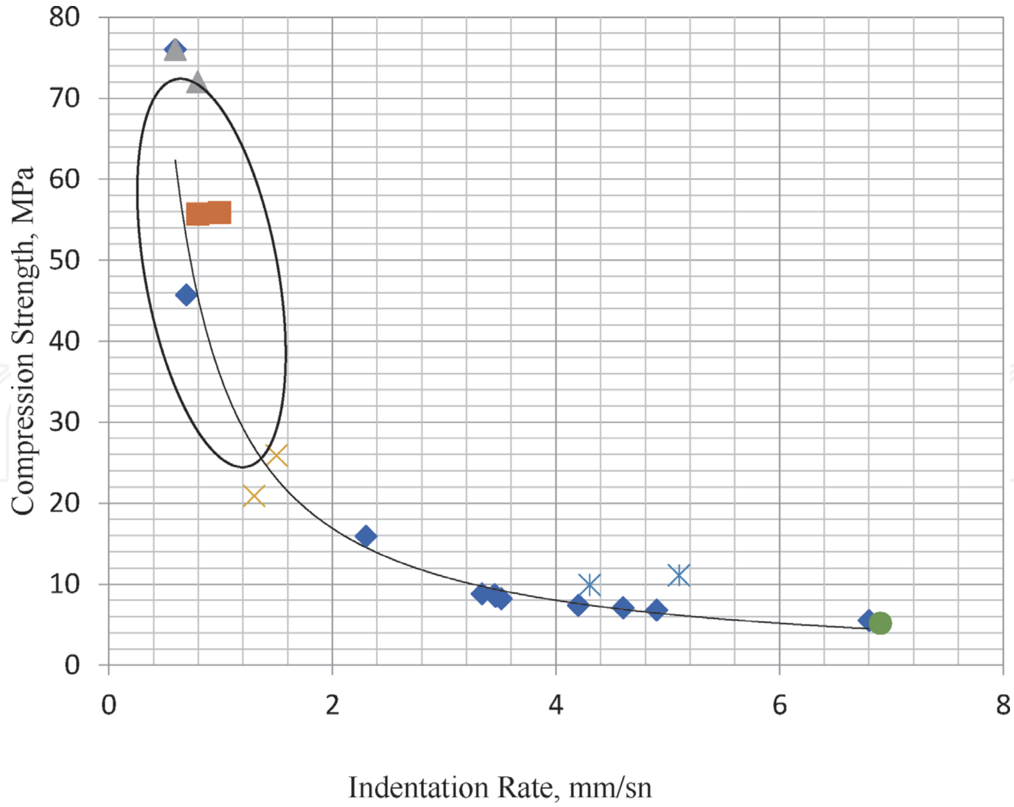

Figure 12.
Compression strength change of the Şırnak aggregates.

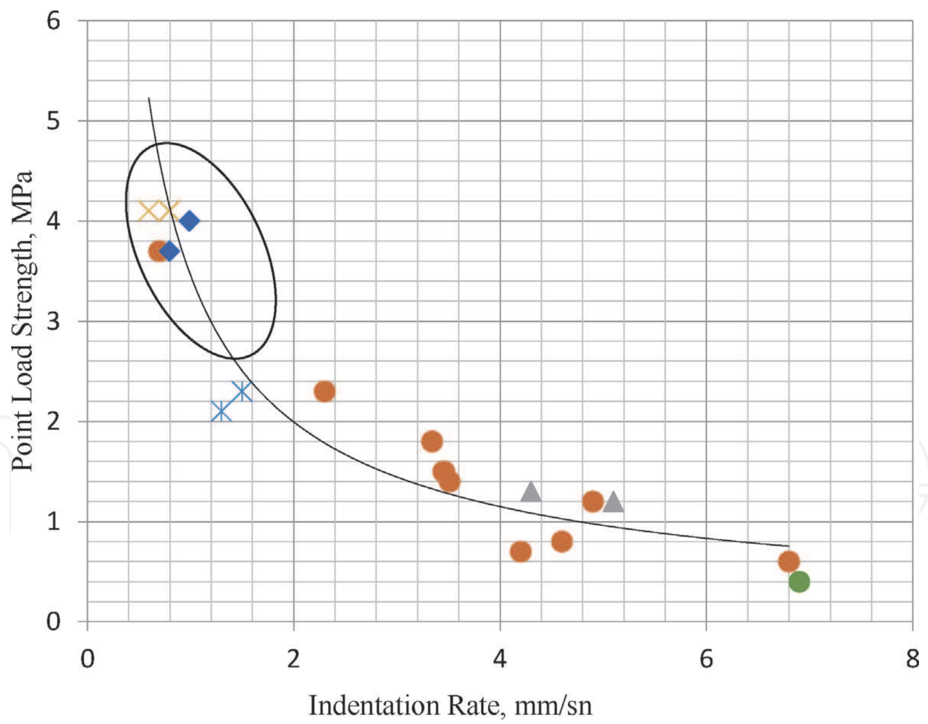

Figure 13.
Point load strength change of the Şırnak aggregates.

The rock samples have also increased the 13.6% of the pore contained in bulk pile as 25 mm fraction showed a pore rate as lower at 9.2%. The results were shown in **Figure 1**. **Figure 1** also proved that the melted interaction of 20 min is sufficient. Hence, the dissolution process reached the PE and ash saturation of the emulsified PE solution by waste machine oil. The pores in the limestone sample reached 13.6% (**Table 4**).

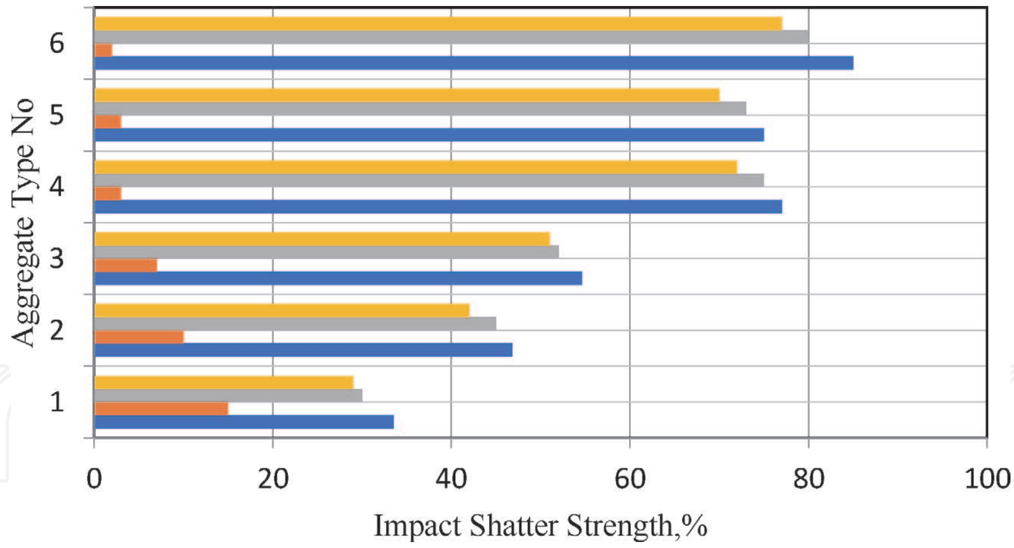

Figure 14.
Histogram view of impact, abrasion resistance: 1. Sırnak porous limestone; 2. Sırnak marl; 3. Şırnak marly shale; 4. Midyat limestone; 5. Şırnak porous limestone; and 6. Şırnak marl.

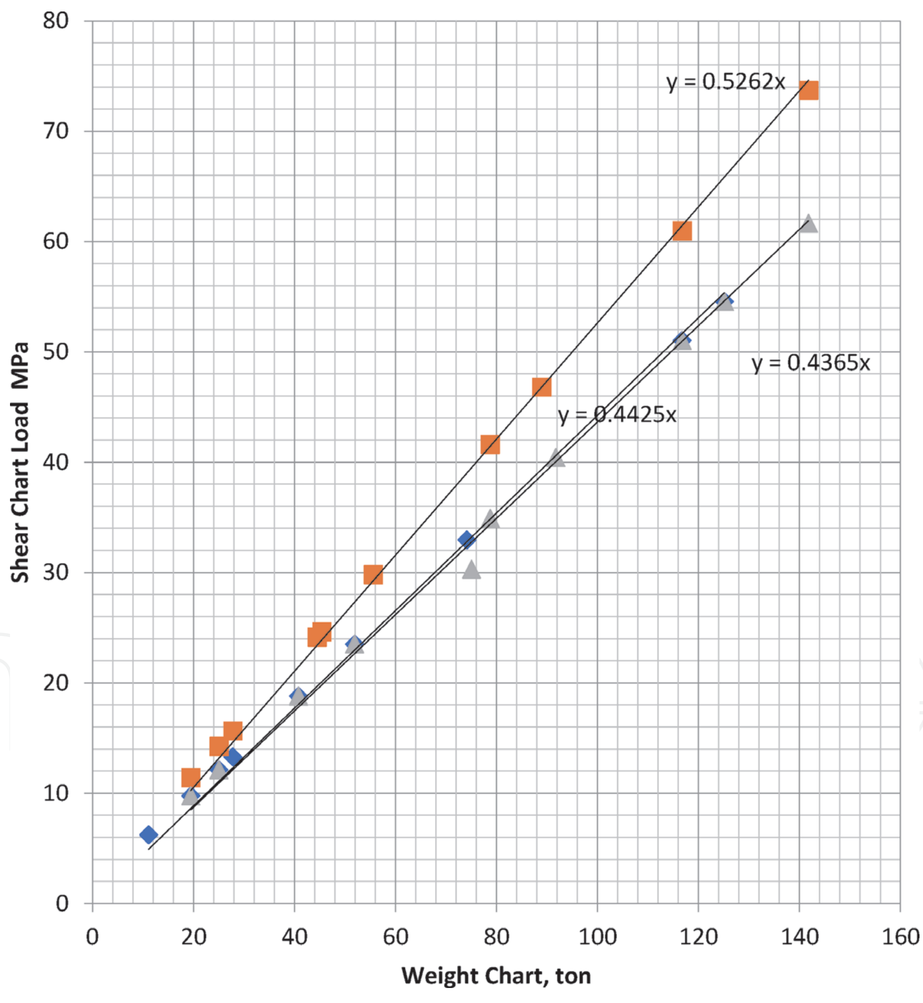

Figure 15.
Chart pattern for Workers in open pit mine excavations for S1 slope. Excavation was completed till 43° slope obtained for overburden.

Porous limestone texture, chemical interaction result, and petrographic changes are seen in **Figure 2**. It was determined that the amount of silicate of 2.3 and 4% of Şirnak altered limestone was changed and the pore size was as micro mesh with a size of 1–3 mm macro 50–300 micron. This pore amount is in microcrystalline

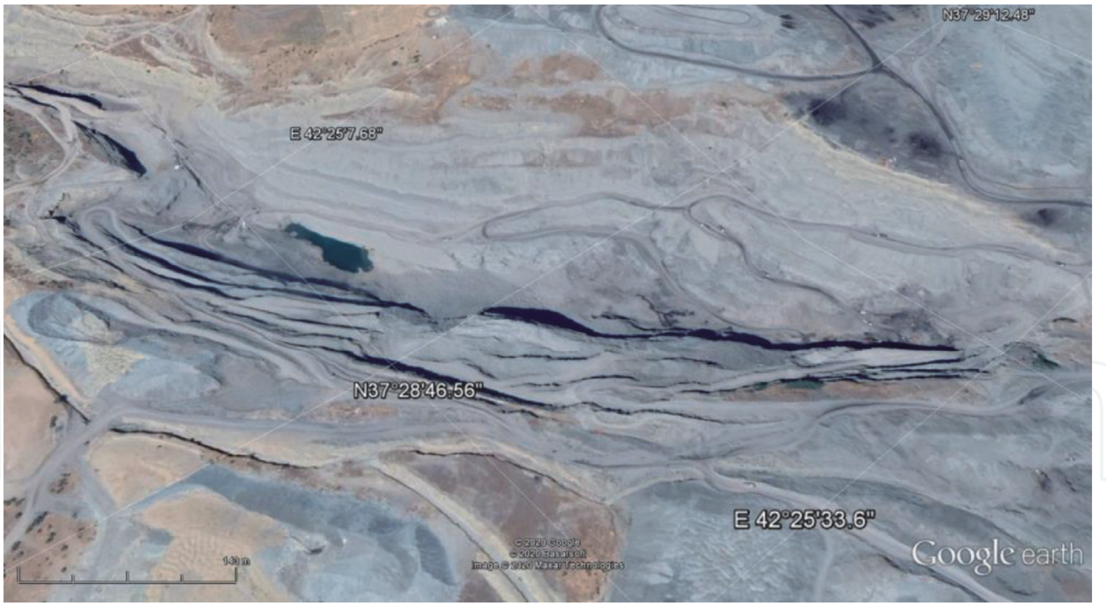

Figure 16.
Open pit mine No.2: excavations for steep slopes—asphaltite excavation.

%Component	Shale powder	Asphaltite slime	Tatvan pumice	Şırnak fly ash
SiO2	43.48	50.50	60.13	41.48
Al_2O3	16.10	14.61	17.22	18.10
Fe_2O3	10.52	24.30	4.59	4.52
CaO	8.48	2.30	2.48	18.48
MgO	3.80	1.28	2.17	4.20
K_2O	2.51	2.51	3.51	2.71
Na_2O	1.35	1.35	4.35	1.95
Ign.loss.	10.9	0.21	4.12	1.9
SO3	0.32	0.12	0.52	0.22

Table 4.
Chemical composition of binder fillers for crack stabilization in the Şırnak asphaltite Avgamasya open pit mine No.1.

microporous structure of 13.4–14.8% silica in Sırnak marly limestone and as 5–30 micron microporous. The degree of chemical interaction in marinated limestone and marl was not sufficient due to the silica content and the microcrystalline pore structure.

4.5 Stability risk survey for S1 slope

According to the information obtained from the drillings carried out by the Special Provincial Administration, the depth of the slope varies 11–20 m. In the investigations, the groundwater level on the slope where the landslide no S1 is located was observed at a base of 25 m. In the stability calculations made on the slope where landslide S1 developed, $c' = 190\ kg/cm^2$, $\varphi' = 22°$, $\gamma_{natural} = 2.97\ g/cm^3$, and $\gamma_{dry} = 2.7\ g/cm^3$. Safety coefficient values of possible sliding surfaces calculated separately according to "saturated" rock were shown in **Table 6**. According to Hoek-Bray [32], the safety coefficient value is determined as 1.25. When **Table 7** is examined, since the boundary safety coefficient is taken as 1.25, it can be easily seen that the sliding slopes S1 and S2 were unstable. It is seen that the sliding surfaces 3 and 4 are very close to the limit value when it is made according to "saturated" rock and it is unstable when it is examined according to "natural."

According to the slope-clay floor combined ground classification (USCS) located in the upper skirts of the south district, the SW-SC group consists of plastic floors. Tectonic events occurring in the region have also triggered movements and continued to this day. Today, it has been observed in the field studies that there are small size movements on the slope after the rains. The slope where landslide risk S1 was developed was covered with color black showed the instability (**Figure 11**). The maximum elevation difference between the top and heel point of the landslide S1 is 75 m, the maximum height of the slope is 110 m, and the slope angle of the slope is 48°.

According to the information obtained from the drillings carried out by the Mining Bureau of Şirnak Administration Authority, the thickness of the slope varies between 11 and 20 m. In the investigations, underground water level was observed on the slope where the landslide number. In the stability calculations on the slope where the landslide S1 is developed, $c' = 199$ kg/ cm^2, $\varphi' = 22°$, $\gamma_{sat} = 2.97$ g/ cm^3, and $\gamma_{dry} = 2.77$ g/cm^3 were used. Safety coefficient values of possible sliding surfaces calculated separately according to "saturated" rocks were shown in **Table 6**. According to Hoek-Bray, the safety coefficient value is determined as 1.25. When **Tables 6** and **7** were examined and analyzed, since the boundary safety coefficient was taken as 1.25, it could be easily seen that the sliding surfaces 1 and 2 are unstable. It was seen that the sliding surfaces S3 and S4 are very close to the limit value according to saturated rock weight.

Shale rocks without drainage develop geotechnical parameters anisotropically. The slopes under compressive load show different shear strength depending on the shear face direction depending on the water content.

$$c_\theta = c_2 + (c_1 - c_2)\ \cos^2\theta \tag{1}$$

where θ is the angle made with the principal stress direction where shear stress occurs as below:

- compressive strength in the direction of θ sliding face;
- normal load stress in the vertical direction; and
- shear stress in the horizontal direction.

Compressive load values in the calculation of design model slope stability cards were given as equation below:

$$F = \sum_{0}^{\mathrm{i}} \mathrm{N}_i \mathrm{F}_\mathrm{i} = \mathrm{N}_i \frac{C_\mathrm{i}}{\gamma H} \cos\beta^i \tag{2}$$

The compression load on the $\mathrm{N}_i$block was calculated as the ground anisotropic shale shear $\frac{C_1}{C_i}$ strength values depending on the slope angle, β. Although safety factor is designed as 1.25 and 1.35, safety factor is preferred as 1.35, according to water content greatly considered.

Due to the differences in fracture distribution, in order to determine the safe slope stability angle in the stress design cards, the sliding risk factor R_c depends on the fracture distribution percentage and angle of the slope angle in the formation, which has a high probability of slide.

The fracture or discontinuity angle t frequency% in the 20 m sliding on slope direction and the variable position in the design card $\frac{dy}{dx}$ were calculated as given in below equations and in **Tables 5–7**

$$R_c = \sum_{0}^{i} R_i F_i \tan\theta = \int_a^b e^{-ti\theta} dy^i \tag{3}$$

$$\frac{dy}{dx} = e^{-ti\theta} dy \tag{4}$$

Curing time (min)	Uniaxial compressive strength (kg/cm^2)				
Compacted binder	1. Sample	2. Sample	3. Sample	4. Sample	Average sample
5% fly ash					
10	205,6	205,6	209,60	203,5	204,55
30	284,5	284,5	288,4	296,5	289,80
15% fly ash					182,99
10	205,6	188,81	198,39	196,1	194,43
30	284,5	304,84	319,7	301,75	308,76
20% fly ash					203,61
10	205,6	251,17	253,9	257,56	254,21
30	284,5	360,79	369,2	360,73	363,57
25% fly ash					205,50
10	205,6	300,24	220,92	241,46	254,21
30	284,5	355,13	356,99	359,21	357,11
30% fly ash					281,89
10	205,6	323,66	316,99	313,72	318,12
30	284,5	381,17	377,42	371,8	376,80

Table 5.
Şırnak limestone aggregate sieve analysis results aggregate type.

Site	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	SF
S1	1210	2150	3270	4180	5460	6210	5740	4130	3550	2230	1.1
S2	1320	2280	3330	4270	5640	6540	5730	4580	3840	2470	1.2
S3	1110	2010	3110	4080	5200	6030	5530	3970	3110	1940	1.3
N1	1200	2100	3200	4100	5400	6200	5700	4100	3500	2200	1.2
N2	1200	2100	3200	4100	5400	6200	5700	4100	3500	2200	1.25
N3	1200	2100	3200	4100	5400	6200	5700	4100	3500	2200	1.3

5 m unit saturated weight charts kN.

Table 6.
Sliding shale landslide risk cross section with slope topography of Şırnak Avgamasya open pit No.1 mining.

Site	Joint 1,	Joint 2	Joint 3	Joint 4	Joint 5	Joint 6	Joint 7	Joint 8	Joint 9	Joint 10	Joint 11	Joint 12	Joint 13	SF 13-12
S1	321/332	515/443	527/453	418/366	546/377	621/556	574/221	513/462	655/555	223/112	418/366	513/462	655/555	1.1
S2	321/332	515/443	527/453	418/366	546/377	621/556	574/221	513/462	655/555	223/112	418/366	513/462	655/555	1.2
S3	321/332	515/443	527/453	418/366	546/377	621/556	574/221	513/462	655/555	223/112	418/366	513/462	655/555	1.3
N1	321/332	515/443	527/453	418/366	546/377	621/556	574/221	513/462	655/555	223/112	418/366	513/462	655/555	1.2
N2	321/332	515/443	527/453	418/366	546/377	621/556	574/221	513/462	655/555	223/112	418/366	513/462	655/555	1.25
N3	321/332	515/443	527/453	418/366	546/377	621/556	574/221	513/462	655/555	223/112	418/366	513/462	655/555	1.3

5 m unit saturated rock block weight points kN (H/V).

Table 7.
Sliding shale landslide risk finite analysis with slope topography of Şırnak Avgamasya open pit No.1 mining.

Safety risk parameter was calculated as 1.42 stable for 400 slopes, but for 500 and 600 slopes, the safety factors decreased to 1198 and 1060. As given in the figure, the equation slope 44.20 has been given a safety factor for a stable slope as 1320 is shown in **Figure 8**.

$$S = \frac{\Sigma(c' + \sigma' \cdot \tan \phi') \cdot \ell}{\Sigma(W \cdot \sin \alpha)} \tag{5}$$

In the observations made on this slope during the field studies, it was observed that it took the material that occurred in the stream and that small breaks and flows occurred after the precipitation. The geological map and landslide cross section and the surfaces where the calculations are made are given in **Figure 17**.

Groundwater movement change should be considered as a hazard and landslide prevention methods appropriate for the site should be determined. In addition, as the study area will be opened to urban use within the scope of the project, research and development of nonslip methods in the region is of special importance (**Tables 8–10**).

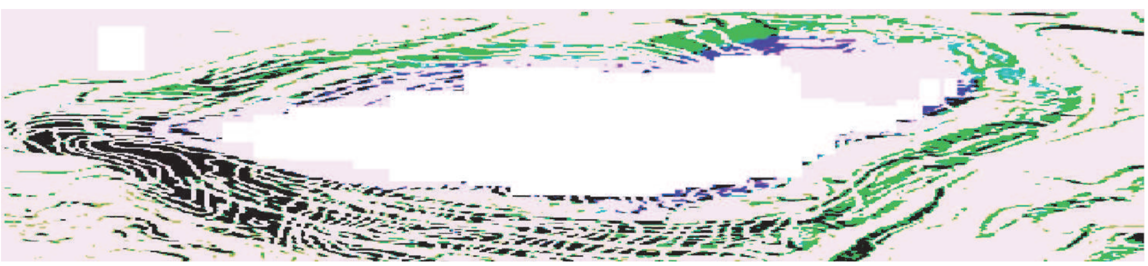

Figure 17.
Sliding shale landslide risk isocontour map; black area is unsafe area.

Chart	Block height	Block width	Block weight (ton)	Block weight (kN)	Block chart share (MPa)	Safety
1	3	4	11,12	109,0872	6,217,489	
2	5	6	27,8	272,718	13,29,372	
3	10	8	74,13,333	727,248	32,94,993	
4	15	9	125,1	1227,231	54,57,176	
5	18	7	116,76	1145,416	51,03364	
6	16	5	74,13,333	727,248	32,94,993	
7	14	4	51,89,333	509,0736	23,51,495	
8	11	4	40,77,333	399,9864	18,79,746	
9	9	3	25,02	245,4462	12,11,435	
10	7	3	19,46	190,9026	9,755,607	500
Total				5554,357	255,1988	1206

Table 8.
Weight chart calculations for S11.

Chart	Block height	Block width	Block weight (ton)	Block weight (kN)	Block chart share (MPa)	Safety
1	5	6	27,8	272,718	15,65,644	
2	7	7	45,40,667	445,4394	24,62,219	
3	12	8	88,96	872,6976	46,80,062	
4	17	9	141,78	1390,862	73,69,786	
5	18	7	116,76	1145,416	60,95,706	
6	17	5	78,76,667	772,701	41,60,992	
7	15	4	55,6	545,436	29,81,289	
8	12	4	44,48	436,3488	24,15,031	
9	9	3	25,02	245,4462	14,2408	
10	7	3	19,46	190,9026	11,40,951	500
Total				6317,967	342,9576	1418

Table 9.
Weight chart calculations for S12.

Chart	Block height	Block width	Block weight (ton)	Block weight (kN)	Block chart share (MPa)	Safety
1	9	9	75,06	736,3386	30,29,683	
2	11	9	91,74	899,9694	40,41,929	
3	15	9	125,1	1227,231	54,57,176	
4	17	9	141,78	1390,862	61,64,799	
5	18	7	116,76	1145,416	51,03364	
6	17	5	78,76,667	772,701	34,91,555	
7	14	4	51,89,333	509,0736	23,51,495	
8	11	4	40,77,333	399,9864	18,79,746	
9	9	3	25,02	245,4462	12,11,435	
10	7	3	19,46	190,9026	9,755,607	500
Total				7517,926	337,0674	1171

Table 10.
Weight chart calculations for S13.

5. Conclusions

As a result of the laboratory experiments carried out on the soil samples, it was determined that the slope material was permeable, the cohesion value ranged between 0.1 and 0.38, the internal friction angle ranged between 17.5 and 22.4, and according to the combined ground classification, the slope material consisted of shale group plastic steep slopes in the top area of low RQD. From the stability analysis performed in the light of this information, it was concluded that the slopes in S1, S2, and N1 are unstable, and the slope S3 and N2 in open pit were stable.

As a result of the field studies, it was determined that the increase in the flow rate at the peak with the melting of snow, especially in May and June, caused severe erosion on the heel of the slopes and thus had a negative effect on the stability of the slope. Chart patterns were obtained on the slopes S1, S2, and S3 to reduce sliding risk.

In order to prevent this situation with clay, it is necessary to accumulate rock material in sizes that the river cannot carry, or the creek must be improved. South and North districts of the Avgamasya open pit No.1 asphaltite mine should be reinforced in the hazardous areas according to ground water. As a result of these shock wave movements, taking precautionary measures according to the slopes and underground water floods, drainage channels should be examined again. For this reason, there is a need to investigate the stability of the slopes that will be opened to urban use.

The importance of extensometer station was very critical for over 20 mm displacement and covering the cracks by mixture of melted plastics and asphalt and facilitates the infiltration of rainwater into the channel reduces the landslide or rock flow. This drainage patterns prevents the masses creep.

The lack of vegetation in the study area prevents benefiting from these effects, which are positive in terms of stability, and hence, there is a reduction in the holding forces that keep the slopes in balance. For this reason, enrichment in terms of vegetation is an important landslide preventing parameter in the region. However, the effect of vegetation on stability will be minimal for sliding surfaces up to 30 m in depth. The weathering causes the rocks to change to a great extent, the bond between the grains to weaken and disappear completely. The rocks, which weaken as a result of weathering in the study area, are easily eroded and change the slope angles and slope altitudes. The weathering observed in the rocks in the study area also contributes negatively to the stability problems. As a result of geotechnical analysis carried out in the study area, it is concluded that very large landslides will not be expected in the future. However, this result does not eliminate the possibility of landslide danger for urban areas and urban development areas. For this reason, especially in large-scale plans such as master zoning plan and application zoning plan, geological hazard in the region should be evaluated and landslide prevention methods appropriate for the site should be determined. In addition, research and development methods to prevent instability in the region are of special importance since the study area will be opened to urban use within the scope of the project.

As a result of laboratory experiments carried out on the soil samples, it was determined that the slope material was permeable, the cohesion value ranged between 1300 and 3800 kPa, and the internal friction angle ranged between 37.5 and 22.1, and according to the combined ground classification, the slope material consisted of Shale, low marly shale, and cracked limestone low RQD group rocks. From the stability analysis performed in the light of this information, it was concluded that the slopes S1, S2, and N1 were unstable, and the slopes S3 and N2 N3 were stable.

As a result of the field investigations, it was determined that the increase in the flow rate at the peak with the melting of snow in May and June caused severe erosion on the heel of the slopes and thus had a negative effect on the stability of the slope. In order to prevent this situation, which is effective on slopes N2 and N3, it is necessary to accumulate rock material in sizes that the stream cannot bear, or the stream should be improved. Sirnak City and the surrounding area, according to Turkey Earthquake Zone Map, are located in the first degree in the danger zone. Since these regions are within the influenced area of the South East Anatolian Fault, frequent earthquakes occur in the region and some tectonic movements occur due to these earthquakes. As a result of these movements, the stability of the slopes is compromised. For this reason, there is a need to investigate the stability of the slopes that will be opened to urban use.

Plants facilitate the infiltration of rainwater into the mass and slow down and reduce superficial flow. This prevents the masses from erosion. The roots of the plants, whose roots reach deep, are mechanical.

Symbols

c' kg/cm^2	effective cohesion
c kg/cm^2	cohesion
Φ'o	effective internal friction angle
Φo	internal friction angle
τ kg/cm^2	shear stress
σ kg/cm^2	normal stress
Is	point load index
Bs	bending strength
Ps	compression strength
Wopt	optimum water content
$\gamma_{Natural}$ g/cm^3	natural unit volume weight
$\gamma_{Saturated}$ g/cm^3	saturated unit volume weight
γ_{Dry} g/cm^3	dry unit volume weight
γkmax g/cm^3	maximum dry unit volume weight
γs g/cm^3	grain unit volume weight
k	permeability coefficient
S1, S2, S3, S4, C1, C2	south and north landslide risk slopes No. 1, 2, 3, 4
S11, C11	sample taken from south and north landslide risk slopes number

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