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IMPROVEMENT OF FOREST ROADS, CASE STUDY: THE ACCESS ROAD TO THE GOLIRAN COAL MINE IN MAZANDARAN PROVINCE, IRAN

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Abstract

Improvement of existing forest roads for easier access to mineral resources and operation is one of the national needs and a factor of economic and tourism development in the forest areas on the southern Coast of the Khazar Lake and in the Highlands of the northern provinces of Iran. Forest resource management can only be sustainable through a well-organized road network designed with optimal spatial planning and minimum environmental impacts. Improving the quality of forest roads leads to reducing mining and transport costs, and improving the livelihoods of the local people However, unscrupulous construction and improper maintenance could have adverse and irreparable effects. Environmental destruction should be minimized in the design and construction of forest roads and engineering principles should not be neglected in this regard. In the long run, Improved Road construction will have positive environmental impacts because road damage due to Erosion and Drift brings environmental damage in addition to economic and social injuries. One of the main factors in the stability and durability of roads is extensive drainage and stabilization of the road shell in inaccessible forest and mountain areas. This article examines environmental and engineering problems, sustainability, and impacts of drainage and stability in the construction and improvement of forest roads based on the access road to the Goliran coal mine in the highlands of Babol county in Mazandaran province, Iran.

Keywords: Forest road network, Environmental impact, Natural resources, Drainage, Stability, Construction.

1. INTRODUCTION

The opening up of mountain forest resources requires integrated planning to balance industrial demand and environmental protection. This becomes more crucial with the use of modern machines for road building, forest harvesting, and the growing need for Coal. Besides these main goals, land ownership and local people's rights and needs must also be respected in terms of fuelwood and fodder supply, water source, scenery, wildlife, etc. These aspects may affect the interests of a village, district, county, or country. For all these purposes, whether they are productive or protective, a well-planned forest road net is the key to performing the necessary work and sustaining the forests as a renewable resource. The design of a road net depends on various factors, such as the resources, terrain conditions, type of forest operations (afforestation, silvicultural treatment, fire protection, logging, and transport methods), technical equipment and machines, labor techniques, and costs, as well as other resource benefits to be considered. Special care has to be taken, when planning and locating roads in steep terrain, to prevent and reduce the erosional impact of roads on the environment.

Within a forest road net one can classify roads:

(a) According to their position:
- Main valley roads
- Secondary valley roads
- Slope roads
- Feeder roads
- Mountain ridge roads

(b) According to the construction:
- Earth roads
- Graveled roads (mechanically stabilized roads)
- Chemically stabilized roads
- Roads with bituminous or oiled surface

(c) According to the intended use:
- Truck roads
- Tractor roads
- Purely opening-up forest roads
- Access roads
- Multiple use forest roads

(d) According to importance:
- Main roads
  (Permanent roads and all-weather roads)
- Secondary roads, feeder roads
  (Seasonal roads)

Nowadays, with the advancement of machinery and facilities the increase in production in the coal mine and the importance of the mine located at the end of the route for economic and social reasons in the region, as well as the need to increase transportation efficiency and reduce production and transportation costs, upgrading existing roads and proper maintenance over the period of operation is essential and inevitable. In this case, the improvement of the Goliran coal mine road is important because the Government wants to improve this road to multiple-use all-weather rod statues. Of course, it's worse nothing that this road was expanded and sandblasted in the mid-80s and turned into a vehicle road. Based on the researcher's observations of the road conditions, geographical location, and climate of the region, the greatest threat to the road is the instability of embankments and bed slopes, Heavy rainfall, and improper drainage along the entire length of the road. For this reason, hydrological studies are so important also we need to stabilize the slopes properly.

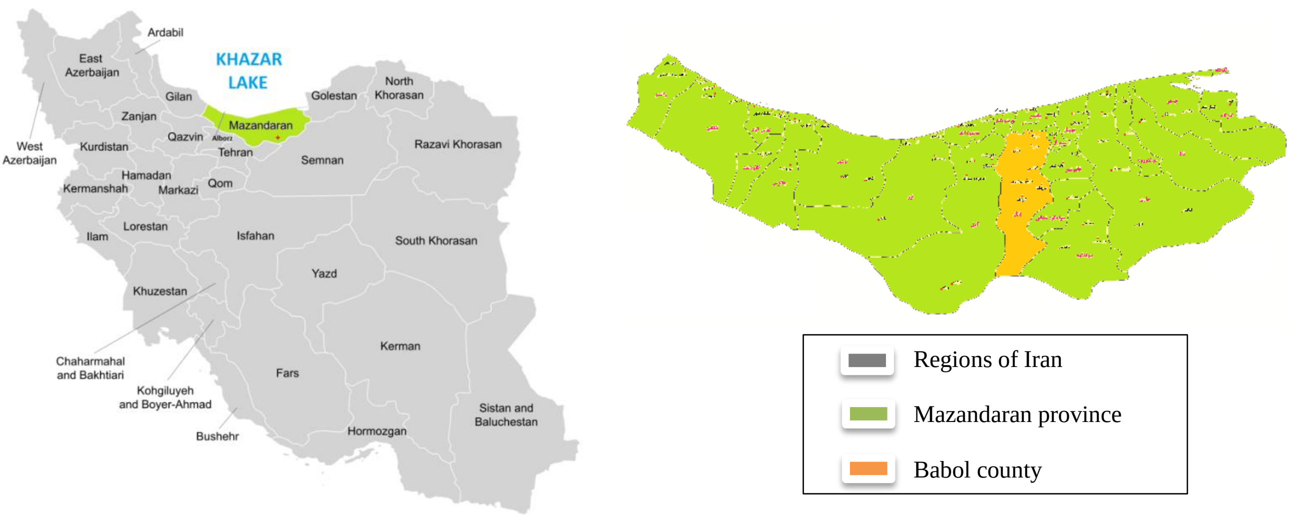


Figure 1. Location of the study area

Figure 2. Road path

1.1 Hydrological Studies

The study area is located on the northern margin of the Alborz Mountain range and south of the Khazar Lake in Mazandaran province. The area has a remarkable altitude diversity ranging from 700 meters at the beginning of the route to about 2300 meters above sea level.

This area is generally affected by the mid-latitude weather systems prevailing over Iran's plateau. The most important air masses that directly affect the region are as follows:

- Polar maritime air masses (MP) originating from the Mediterranean Sea, the Black Sea, and the southern Atlantic Ocean from the north and northwest, and tropical maritime air masses (MT) originating from the Indian Ocean and the Red Sea from the south and southwest can sometimes intensify rainfall in the region as a moisture feeding agent.

- Polar continental air masses (CP) from early December to early March alternately perform in the region from the northeast with Siberia as their source and also from the northwest that originates from Europe. The temperature accompanying this air is very low and mostly below zero.

- Continental tropical air masses (CT) also usually form in the region in summer. These masses mainly cause local winds and dust.

- Continental frozen air masses (CA), which are very cold and dry and rarely move towards Iran in winter from Siberia or northern Europe, affect northern, western, and even central Iran.

Estimating runoff is one of the most important components of hydrological studies. In this regard, selecting the design rainfall, which is usually done using intensity-duration-frequency (IDF) curves and for rainfall with a known duration and frequency, is the most fundamental step in estimating runoff. The design rainfall, which is the generator of the design runoff, is defined and determined through specifications such as total height, total duration, spatial distribution, and ultimately temporal distribution of rainfall.

Rainfall statistics, especially maximum daily rainfall, and short-term rainfall are extremely important in hydrological studies and designing systems for collecting and disposing of runoff. Especially since regular and systematic statistics of surface waters are not available and many of the studied basins lack hydrometric stations, estimating their runoff requires the use of rainfall statistics. Completion rainfalls should be extracted from synoptic charts of the country's meteorological organization or stable rain gauges of the Ministry of Energy and after verification, correction, and completion should be prepared in time series for subsequent analysis. Maximum daily rainfall statistics, including maximum Daily rainfall each year, are directly applicable in many hydrological studies.

1.1.1 Precipitation Plan

Flood estimation is one of the most important components of hydrological studies. In this regard, selecting the design rainfall, which is usually done by using intensity-duration-frequency (IDF) curves for rainfall with a known duration and frequency, is the most fundamental step in flood estimation. The design rainfall that generates flood is defined and specified by characteristics such as total height, total duration, spatial distribution, and ultimately temporal distribution of rainfall.

Rainfall statistics, especially maximum daily rainfall, and short-term rainfall are of great importance in flood studies and the design of flood collection and disposal systems, especially since regular and systematic statistics of surface runoff are not available in our country and many of the studied basins lack hydrological stations. Therefore, estimating their floods requires the use of rainfall statistics. Short-term rainfalls should be extracted from synoptic charts of the country's meteorological organization and stable rain gauges of the Ministry of Energy. After verification, correction, and completion, they should be prepared in time series for subsequent analyses. Maximum daily rainfall statistics, which include maximum daily rainfall during each year, are directly applicable in many flood studies and therefore their collection and completion are necessary for subsequent analyses. As expected, rainfall in the forest at different kilometers along the route varied with the data from the stations, but the average rainfall on the road was close to the average rainfall of the Shirgah station.

Table 1. Average monthly and annual rainfall in the study area stations (mm)

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total annually
Goran-talar	77.8	84.9	93.4	70.6	75.9	57.6	73.5	72.4	111.1	133.3	97.3	102.9	1050,7
Babol-Slaughterhouse	66.6	65.1	62.2	40.9	31.1	22.1	28	28.2	58.7	85.5	97.3	93.5	679.3
Qarakhil	66.6	67.6	70.6	51.4	37.8	34.9	34.1	37	75.5	88.2	93.9	84.6	742
Kiakola	68.5	72.1	66.3	46.9	28.8	21.6	27.2	31.1	63.1	91.4	100	95.5	712.5
Galugah	77.4	88.8	95.7	76.1	78.7	63	70.4	69.7	118.5	147.4	97.7	92.9	1076.3
Shirgah	81.4	85.9	91.5	88.9	76.7	55.9	78.9	76.8	111.4	123.5	106.7	93.9	1071.5
Pol sefid	59.5	54	58.5	48.2	52.2	36.6	37.1	38.9	48.4	52.5	54	58.5	598.3

Table 2. The temperature of the Firouzjah evaporation station (Celsius)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total annually
Average	3.7	3.3	6.1	9.3	12.8	16.9	18.1	20.1	17.6	14.7	9.9	5.9	11.5
Min. Average	-1.15	-1.6	0.34	3.5	7.9	12.3	14.3	15.5	13.5	9.85	**5**	0.77	6.7
Max. Average	10.1	9.6	12.1	15.7	19.4	22.9	23.5	25.7	22.99	20.2	15.2	11.4	17.4

1.1.2 Climate Classification

The climate zoning of Iran based on the De-Martonne index is shown in Figure 3, which shows that there are six main climatic types in Iran. Most of Iran is made up of a dry climate and then a semi-dry climate. As we move from south to north of the country, the area of dry climate decreases, and the area of humid climates increases. The Alborz Mountain range separates two contrasting climates, separating the lowlands of the Caspian Sea from the central plateau and western mountain ranges, such as dams that prevent Mediterranean moisture from entering the Iranian plateau and trap humidity in their foothills. In the central plateau of Iran where dry climate dominates, due to lack of moisture and absence of clouds in the sky, the range of temperature changes is very high in these areas, which is why we see cold and harsh winters and hot and dry summers. The area of other climates has been much less than that of dry climates and for this reason, Iran is generally referred to as a dry country (Masoodian 2003). But as we see in Figure 3 Climate data comes from station and field observations Climatic type of the Project zone is Very Humid.

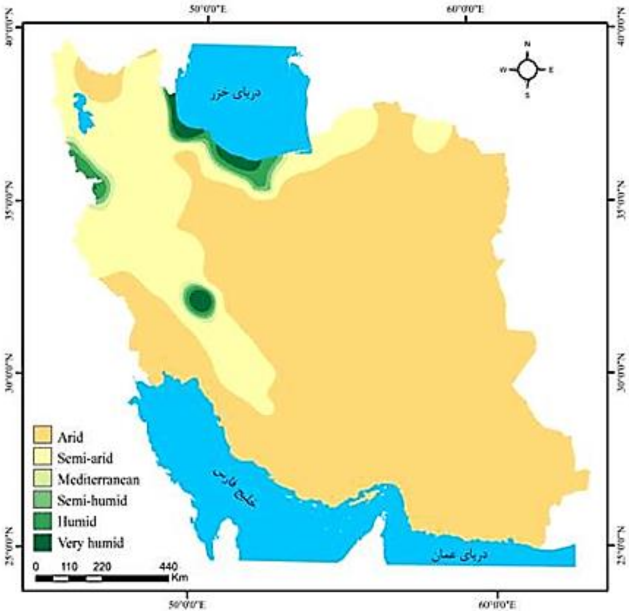


Figure 3. Climate classification map of Iran based on the De-Martone index (1995-2019)

1.2 Geological Studies

This mine is located approximately 35 kilometers south of Babol and 500 meters south of the village of Firouzjah. To get to this mine, you need to head south and after traveling about 27 kilometers and passing through many twists and turns, you will reach the area of the Goliran coal mine. According to the 1:100,000 geological map of Qaemshahr, the route under study is located on the upper sedimentary part of the Shemshak Formation. Based on studies conducted, these sediments are mostly composed of siltstone, sandstone, mudstone, and conglomerate.

The Alborz Mountains have been subject to historical earthquakes for many years, destroying many cities and villages. According to Chalenko, in modern times (such as Pliocene and Quaternary), the Iranian block has moved westward and the southern Khazar block has moved eastward. On the other hand, the Iran and Afghanistan plates can be described as two floating or semi-floating ice floes that have formed a small continent by joining together.

By referring to the reason for the emergence of the southern Khazar Lake, we must pay attention to the issue of the existence of tensile phases. The southern Caspian region has been formed in a tensile field over the past 5 million years with prominent evidence of the effects of this tension, which has resulted in severe subsidence in this basin, especially in the central part of the southern Caspian. If we move from the shores of the Caspian Sea towards the Alborz Mountains, we will face large tectonic structures that provide a suitable location for large earthquake centers.

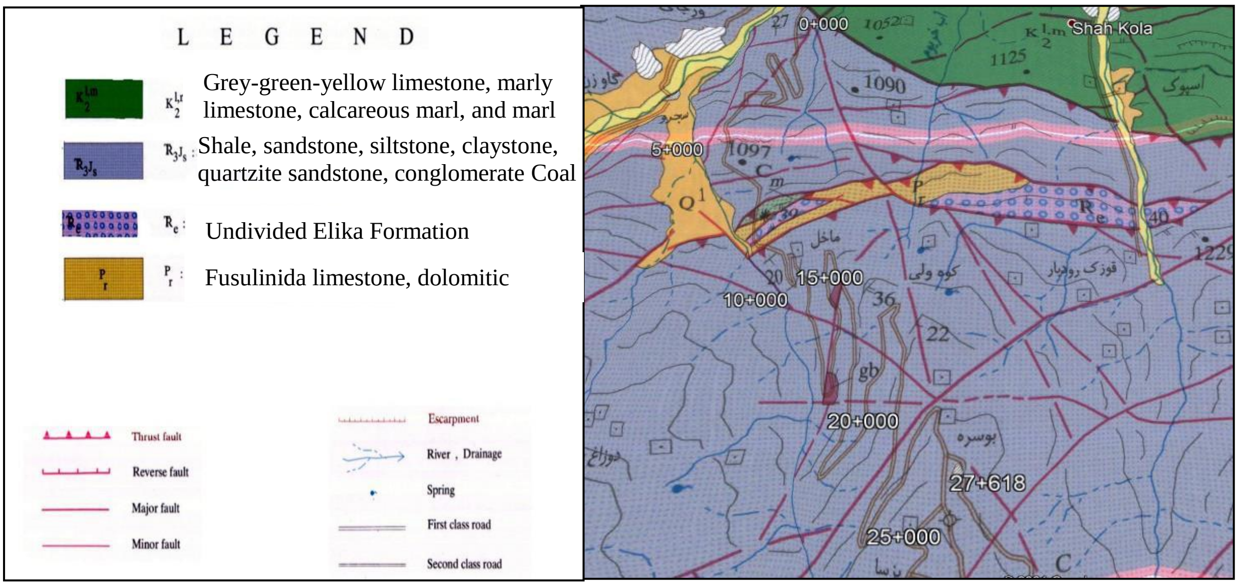


Figure 4. Road route Geological map

Given the important faults of the region the statistics of continuous earthquakes and geological maps that show the faults of Iran and the region, it seems that the studied area is in relatively active areas in terms of earthquake activity. Although the earthquake potential of the region is high, especially in mountainous areas, it decreases as we move away from mountainous areas and approach floodplains. At the same time, according to the earthquake hazard map of Iran prepared by the International Institute of Earthquake Engineering and Seismology in 1999, the studied route is in an area with high earthquake hazard and acceleration of about 0.3 g. Given the earthquakes that have occurred in the region, an acceleration of 0,3g is not far-fetched.

2. METHODOLOGY

Based on Hydrological and Geological data, the importance of drainage and stabilization of alluvial fans is evident. In the following, methods of drainage and stabilization of alluvial fans will be discussed.

2.1 Study Area

In this study, a forest road within the Hyrcanian forests in the Firouzjah region was chosen as the research area. The starting point of the road route is 700 m high from the sea, and the road ended at a height of 2300 m. The total length of the road is 27+618 km, and at the same time, the longitudinal slope of the road route varies between 2%-10%.

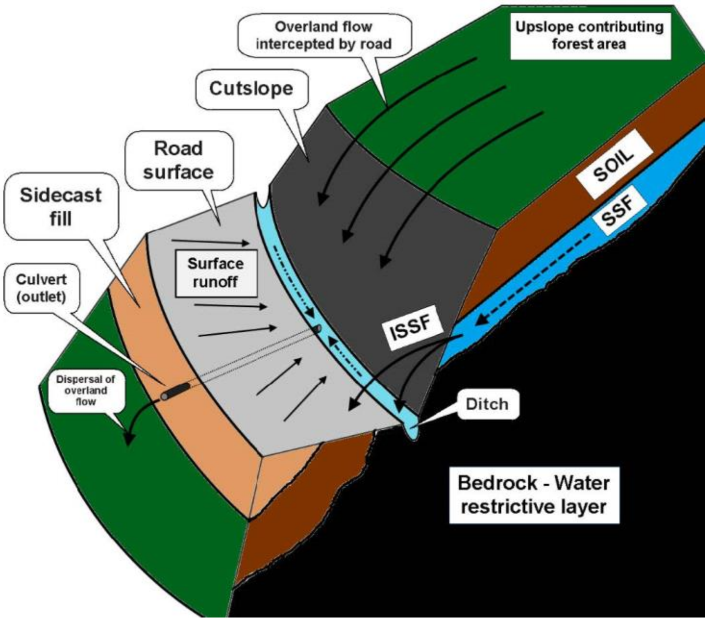


Figure 5. Schematic representation of forest road cut slope, depicting the overland flow, subsurface flow (SSF), and intercepted subsurface flow (ISSF).

2.2 Forest Roads Impact

It is widely accepted that forest roads are highly compacted and present very low infiltration rates, in most cases less than 5.0 mm/h. These low infiltration rates trigger the generation of Horton infiltration-excess overland flow, even during moderate or small rainfall events. Only a few millimeters of precipitation, ranging between 3 and 6 mm, could generate infiltration-excess overland flow. Derived from forest road surfaces, the forest road runoff rates are considerably greater than the runoff from undisturbed hill slopes. Well-constructed roads are safe, minimize environmental impacts, and are cost-effective to build. Implicitly, a major component to meet these objectives is constructing a stable road. Stabilized cuts and fills are therefore an essential part of a well-constructed road. This includes the ongoing stability of cut batter slopes, constructed fill slopes, and slopes adjacent to waterways, river margins, culverts, and bridge abutments. All components of the road need to be stable – the cut banks, ditches, road carriageway, berms, and fill slope. A core component of road stability is water control. Diluting and dispersing, especially away from fills, is a fundamental requirement of any road.

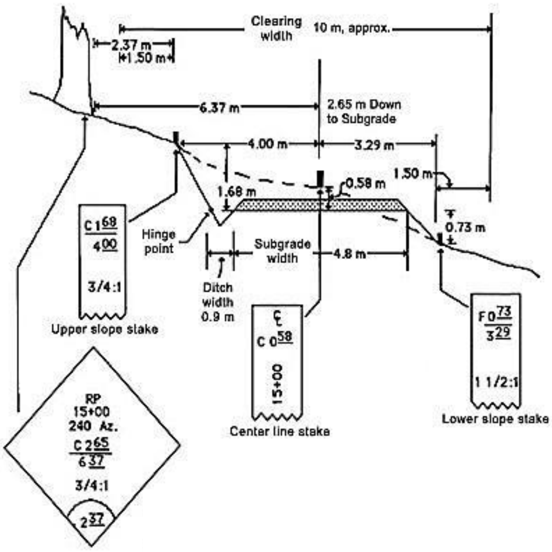


Figure 6. Road cross section showing construction pieces of information.

Table 3. Road construction equipment characteristics. (From OSU Extension Service, 1983).

Criteria	Bulldozer	Front end Loader	Hydraulic excavator	Dump trucks scrapers	Farm tractors
Excavation mode (level of control of excavated materials)	Digs and pushes; adequate control (depends on blade type)	Minor digging of soft material; lifts & carries; good control	Digs, swings, & deposits; excellent control; can avoid mixing materials long-distance material movement; exællent control	Scrapers can load thernselves; •top down' subgrade excavation; used for small quantities	Minor dgging and carrying; good control because it handles
Operating distance for materials movement	91 m; pushing downhill preferred	91 m on good traction surfaces	m (limited to swing distance)	No limit except by economics; trucks must be loaded	31 m (approximately)
Suitability for fill construction	Adequate	Good	Limited to smaller fills	Good for larger fills	Not suitable
Clearing and grubbing (capacity to handle logs and debris	Good	Adequate	Excellent	Not suitable	Handles only small materials
Ability to install drainage features	Adequate	Digging limited to soft materials	Excellent	Not suitable	Adequate for srnall tasks
Operating cost per hour	Moderate, depending on rrHZhine size	Relatively low	Moderate to h@h, but productivity excellent	Very high	Low
Special limitations or advantages	Widely available: can match size to job; can do all required with good operator	Cannot dig hard material; may be traction limited	Good for roads on steep hillsides; can do all required except spread rock for rock surfacing	Limited to moving material long distances; can haul rock, rip rap, etc.	Very dependent on site conditions and operator skill

Poor practice can lead to significant sedimentation and high maintenance costs until cuts and fills self-stabilize. Fixing poor construction is often more expensive than doing it right the first time.

Figure 7. Goliran Road Widening

Road networks in mountainous forest landscapes can increase the susceptibility to shallow land sliding by altering subsurface flow paths. This is because roads can act as conduits for water and increase the amount of water that infiltrates the soil. This can lead to an increase in pore water pressure and a decrease in soil strength, which can increase the likelihood of landslides. This is because roads can increase the amount of surface runoff by reducing the amount of water that is absorbed by vegetation and soil. The increased surface runoff can then infiltrate the soil, also Human activity: mining, traffic vibrations, or urbanization change surface water drainage patterns. For all of this, if we didn’t design ideal systems for Drainage and Slope stabilizing in such a rough region the Roads that we built could not do their jobs and we will have a chain of problems that need a large amount of money and effort.

2.3 Drainage

In this section, based on the results of hydrological studies, the technical structures of hydraulic studies are determined. To increase the coefficient of confidence, the maximum flow rates obtained from the Rational method are based on determining the diameter of the culverts. Currently, only 0.5-meter pipe culverts have been used on the current route and that too insufficient. These culverts quickly become clogged in forest environments due to their small diameter and are difficult to clean and aerate. Therefore, a diameter smaller than 1 meter is not recommended for culverts on this route. The capacity of a culvert depends on many factors. The most important of these factors are the slope of the ground, the roughness of the culvert bed, the shape of the culvert entrance, the upstream and downstream water levels, and the length of the culvert. Therefore, it is not possible to determine the exact capacity for each culvert and it depends on the location of each culvert. However, assuming an average height for flow in the culvert and using Manning’s formula, an approximate capacity for each culvert can be calculated. Manning’s equation is defined as follows:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2} \quad \text{eq.1}$$

Where Q is the Culvert discharge (m^3/s), n is the channel bed roughness (n=0.05), R is the hydraulic radius (calculated from R = A/P, in which, A is the cross-sectional area and P is wetted perimeter), S refers to Average slope of the channel bed, and A is the cross-sectional area of the channel (m^2).

Table 4. Passing Capacity of Culverts

Width (m)	Flow Height (m)	Slope (%)						
		0.5	1	1.5	2	3	4	5
1	**0.5**	0.28	0.40	0.49	0.56	0.69	0.79	0.89
1.5	**0.75**	0.83	1.17	1.43	1.65	2.03	2.34	2.62
2	**1**	1.78	2.52	3.09	3.56	4.36	5.04	5.63
3	**1.25**	4.11	5.81	7.12	8.22	10.06	11.62	12.99
4	**1.5**	7.66	10.83	13.26	15.31	18.75	21.66	24.21
5	**1.75**	12.62	17.84	21.85	25.23	30.90	35.68	39.89
6	**2**	19.16	27.10	33.19	38.33	46.94	54.20	60.60
7	**2.25**	27.46	38.84	47.58	54.93	67.28	77.69	86.86
10	**2.5**	49.70	70.29	86.08	99.40	121.74	140.57	157.16
12	**2.75**	71.23	100.74	123.38	142.47	174.48	201.48	225.26
15	**3**	105.78	149.59	183.21	211.55	259.10	299.18	334.50

2.3.1 Considered Culvert:

A precast concrete culvert with 2 m width and 1 m height was used in the area.

1- The amount of entrance submergence is 85% which means 0.85 meters.

2- The maximum Manning's roughness coefficient for the concrete box is 0.016.

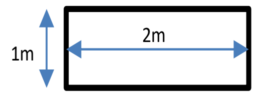
3- Considering that the output of all the water is towards the valley and in the form of rapid flow and any case needs protection, no limitation has been considered for the output speed.

4- The entrance of the culvert has been considered with a 30-degree angle on both sides.

5- Considering the formation of supercritical flow, the culvert is of the upstream control type. Therefore, the inlet conditions determine the flow rate and a change in slope does not cause much change in the flow rate.

Table 5. Flow rate and slope relation

Slope %	Q max cms	flow height m	V max m/s
1,00	2,25	0,85	2,58
2,00	2,30	0,85	2,97
3,00	2,35	0,85	3,26



One of the most important points that should be considered in drainage in forest areas is the issue of debris and the inspection of culverts in a systematic manner. Because the presence of branches, leaves, flowers, and path debris can cause blockage of the culvert with any dimensions and length. Also, the culvert bed and the culvert underpass should be protected in the best possible way so that in critical situations it does not cause total or partial displacement of the culvert and disrupt its function. Regarding the implementation of culverts, it must be considered that the output of each culvert must be protected by stone or gabion. Due to the high slope of the culvert output, it is in the form of a landslide, and therefore in such cases, the culvert output is severely eroded in a short time and becomes empty underneath (Figure 8). In such cases, before and after the culvert, it must be protected by a retaining wall.

Figure 8. Severe erosion of the output of the old waterway

The minimum longitudinal slope for culverts is recommended to be equal to 3%. This minimum is necessary to ensure the complete discharge of the culvert from soil debris and sediment. During implementation, a longitudinal slope of 6% was considered.

Figure 9. An example of full protection of a culvert outlet downstream with natural materials

Figure 10. An example of preparing the placement of prefabricated concrete Culverts

Figure 11. Placement of Culvert boxes

In a way, the Drainage and Stabilization of the trenches are dependent and complementary to each other, and without the existence of one, the other has no meaning. The transfer of surface runoff and subsurface flow along the road will be the responsibility of the side ditch, and all cross-sectional slopes of the road profile must be directed as much as possible toward the ditch to prevent road shoulder erosion (Valley side erosion). This critical issue has not been considered in the design of old and existing roads in the area and has led to road shoulder erosion along the route, which is one of the most principal factors in left deviation and road accidents in forested and mountainous areas. Given that the transfer rate through the ditches will be less than 1 cubic meter per second in any case, assuming an 8 percent slope and a maximum flow rate of 1 cubic meter per second, and assuming Rock lining for the ditch, The required surface area for a flow rate of 5 meters per second will be 0 square meters, and a required surface area for a flow rate of 0.21 square meters must be provided. If the ditch is not covered, the required surface area will be 0.4 sqm.

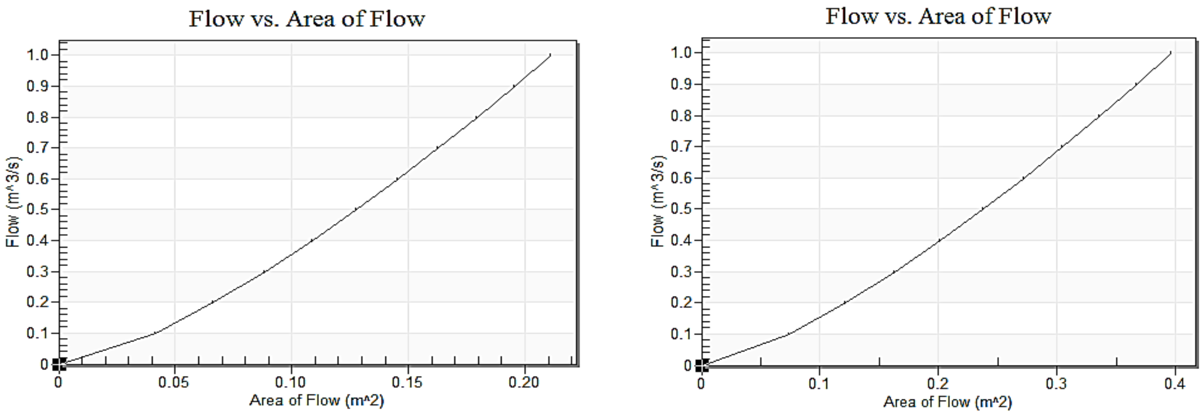


Figure 12. Plotted area vs Flow rate for the channel (a) without and (b) with cover.

It is especially important to use natural materials such as stone and wood in the construction of technical structures as much as possible in forested areas to minimize damage to the ecosystem. The aim is to avoid creating exposed concrete surfaces that make the forest look ugly and damaged. Of course, it is essential to note that unfortunately in Iran, due to the unfamiliarity of engineers with stone and especially wooden structures and a misconception that concrete is more suitable for project implementation without considering the ecosystem of the region and the future, they always consider concrete as the most suitable for project implementation. However, my colleagues and I have tried to use natural materials as much as possible, which I will refer to in the section on protecting the embankment slopes as shown in Figure 14, and lining with stone in places where there is a possibility of ditch erosion.

Figure 13. Removing Sludge and sediments, reviving the existing roadside ditch

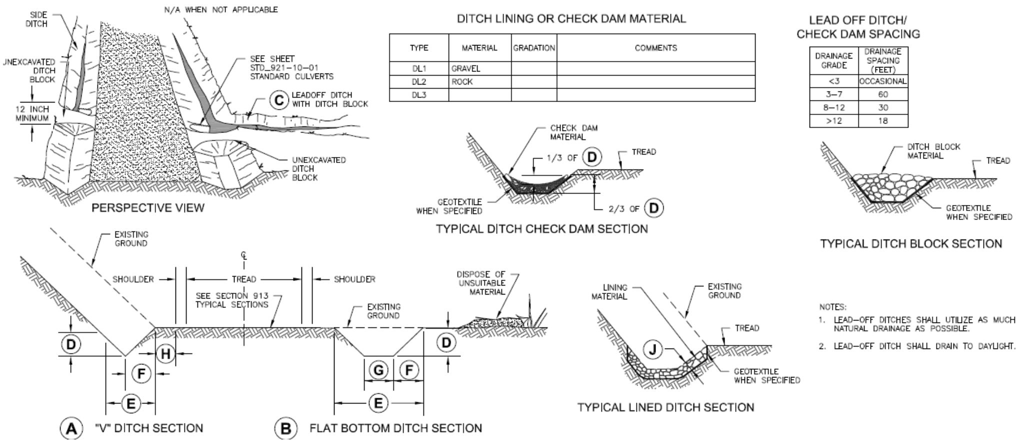


Figure 14. Typical ditch sections STD 925-01 (U.S DEPARTMENT OF AGRICULTURE, FOREST SERVICE)

In this regard, after removing the existing Ditch sludge and sediments, and rockfill section for protecting the road shoulder or digging ditches by the grader, we intended to rehabilitate and increase the efficiency and life period of the roadside ditches by constructing check dams in areas with the steep slope as shown in Figure 10 and lining with stone in places where there is a possibility of ditch erosion. There are two reasons for this. First, reducing the permeability of the ditches by concreting the surfaces as happens with road construction increases the volume of surface runoff. Increasing the volume and speed of surface runoff downstream and in the transverse culverts will destroy the culvert heads, increase water infiltration at these sections, reduce soil shear resistance at the culvert location, and increase the likelihood of landslides. Second, one of the most important issues in the region is preserving the natural beauty of the forest. As noted in the US Forest Service notes, it is always important to preserve natural drainage as much as possible. But unfortunately, we are faced with tragedy in Goliran road ditches.

Figure 15. The concrete lining of the ditches without meeting the required minimums (2023 Summer)

Concrete as you see in Figure 12 can have negative impacts on the environment. In the jungle, concrete can be particularly problematic because it can lead to deforestation and habitat loss for animals. Additionally, as we mentioned above concrete can cause soil erosion and water pollution.

2.4. Stability

This section is devoted to the study of static and pseudo-static stability of the slopes of the Goliran mining project. The geological data of each of them has been estimated based on field measurements. To investigate the above and determine the geological characteristics of the soil units, field measurements, and engineering geological surveys have been carried out. In the case of non-optimal slope design, there is a possibility of forming tensile cracks, instability, sliding, and destruction of the sloping wall. AASHTO and FHWA regulations have been used to limit the coefficient of confidence. So, the coefficient of confidence is 1,5 in static mode and 1,1 in dynamic mode (pseudo-static). Also, the maximum acceleration of strong ground motion in Iran has been presented based on the relative seismic hazard zoning map (standard 2800), in which in my study area, the maximum horizontal acceleration component is about 0.3g.

To analyze the stability of the slopes under discussion, the limit equilibrium method has been used in both static and dynamic modes. For this purpose, limit equilibrium principles and SLIDE software have been used. Also, due to the existence of layering, discontinuities, and main fractures in some rock units of some slopes, proportional kinematic analyses have been presented under critical conditions in some slopes." It should be noted that for the kinematic analysis of the slopes, for sections with lithology of the rock slopes, using geometric and specifications such as slope and slope extension (Dip & Dip direction) of fractures and layering surfaces, Schmidt network has been used, the results of which are in the relevant section.

Each slope mentioned is subject to three important types of instability that are analyzed based on the existing fracture and separation surfaces in the rock mass. These three types are (figure 13):

- Wedge instability

- Planar or layer instability

- Toppling instability

Slope instability is caused by the effect of gravity on masses of materials that can slowly creep, fall freely, slide along a fault plane, or flow like a fluid. Numerous factors affect the slope instability and instability of the slopes under study. In this section, the most crucial factors affecting the instability of the slopes under study are mentioned:

1- Road construction and embankment of the overpasses have caused the balance of driving and resisting forces against slipping to be disrupted and in some overpasses, the driving forces of slipping are more than the resisting forces against slipping and cause the movement of slopes. Also, some slopes are on the verge of movement.

2- Groundwater and surface waters are also considered effective factors in the instability of overpasses. The rise of groundwater in overpasses due to rainfall or drainage of surface waters causes saturation of overpasses. The effect of this factor is more on fine-grained materials. In fine-grained materials that have poor drainage, these conditions cause the production of seepage pressure and a decrease in the effective vertical stress on the surface of the slope and consequently a decrease in the shear resistance of the materials. Also, increasing water means increasing the weight of the slope and facilitating its gravitational movement.

3- Morphology susceptible to sliding is one of the other effective factors in the instability of these overpasses. The high slope and height of the overpasses have caused them to be in a critical stability condition. To prevent slope instability or design a stable slope, the following three methods can be considered:

- Relocation of the design site.
- Reduction of driving forces (motivators).
- Strengthening resisting forces against displacement.

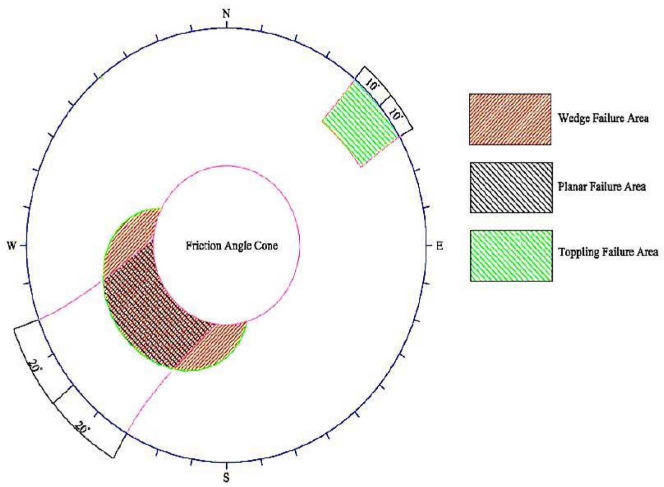


Figure 16. Range of Wedge, plane, and overturning instability in kinematic analysis

The main action to avoid the risk of slipping is to identify areas with weak drainage or active points in terms of displacement and settlement precisely in the design study stage. This knowledge will help a lot in deciding on the design site or relocating it. In these studies, if the safety factor against slipping is greater than one, it can be expected that the minimum reduction in resisting forces (for example, due to rising water levels) will cause instability. Since the criterion for instability is the collapse of the driving and resisting forces, reducing the weight of the sliding mass will reduce driving forces and consequently increase confidence against displacement. Reducing slope angle, terracing and soil drainage, and using lightweight materials in embankments are examples of methods for reducing sliding mass weight and consequently reducing driving forces. Another method to prevent slope instability is to increase resisting forces against displacement. For this situation, either external forces such as retaining walls must be applied to resist earth pressures or internal resistance of the sliding mass must be increased so that the slope remains stable. In general, it can be said that for overpass stability, both reducing driving forces and increasing shear resistance of sliding surfaces can be done.

To reduce driving forces, geometric methods such as reducing height, reducing slope, terracing the slope, and improving drainage can be used. To increase shear resistance, various methods such as ground improvement, mechanical modification, use of retaining structures, gabions, reinforced soil, etc. can be used. Choosing the proper method for stabilizing overpasses based on the characteristics of rock overpasses, implementation constraints, implementation costs, etc. is done. In general, it can be said that both reducing driving forces and increasing the shear resistance of sliding surfaces can be done for overpass stability.

In the following, two examples of long trenches and Stabilization methods in the project will be analyzed with Slide 2 Software.

- ❖ Km 1+180:

- ❖ Between kilometers 1+160 to 1+200 of the studied route, an overpass is found that has a maximum height on the right side of the route and is about twenty-five meters at around kilometer 1+180 and the length of the overpass is about 40 meters.

The lithology of the sediments and rocks of this overpass includes about 1 to 2 meters of clayey soil sediments and surface layers and forest soil and under it are destructive sediments of conglomerate type with cementitious lime that have pebbles in the range of sand to gravel. Also, the existence of sedimentary layers and lenses with silty sandstone geology that have cementitious - lime is also evident in this overpass. It is suggested that an exploratory guess be drilled at kilometre 180 + 1 to a depth of about 26 meters to clarify the columnar geology and soil and rock engineering parameters of this overpass so that its information can be used in analysing the stability of this overpass.

Figure 17. Conglomerate lithology of the trench body km 1+180 (top and bot)

According to field observations and similar projects, the internal friction angle of this rock is mostly about 35 degrees conglomerate, its cohesion parameter is about 100 kilo Newtons per square meter and its density is about 25 tons per cubic meter. Since there is no clear layering and the lithology of the body of this overpass is massive, the stability analysis of this overpass has been presented using Slide software by considering the above assumptions and a 25-meter-high right wall with a slope angle of 63 degrees (2 vertical - 1 horizontal), with 3-meter berms and an 8-meter step height for the right slope. It provides a static safety factor of 1.68 and a pseudo-static safety factor of 1.32.

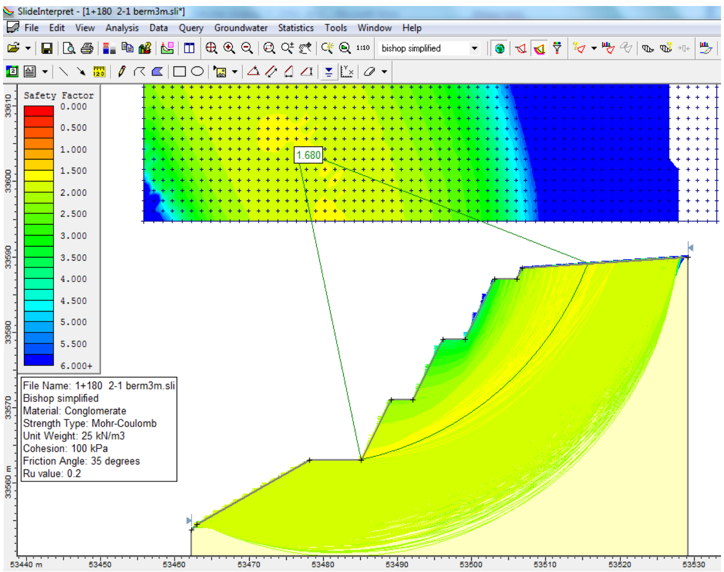


Figure 18. Cross section of right-side trench km 1+180, Static analysis

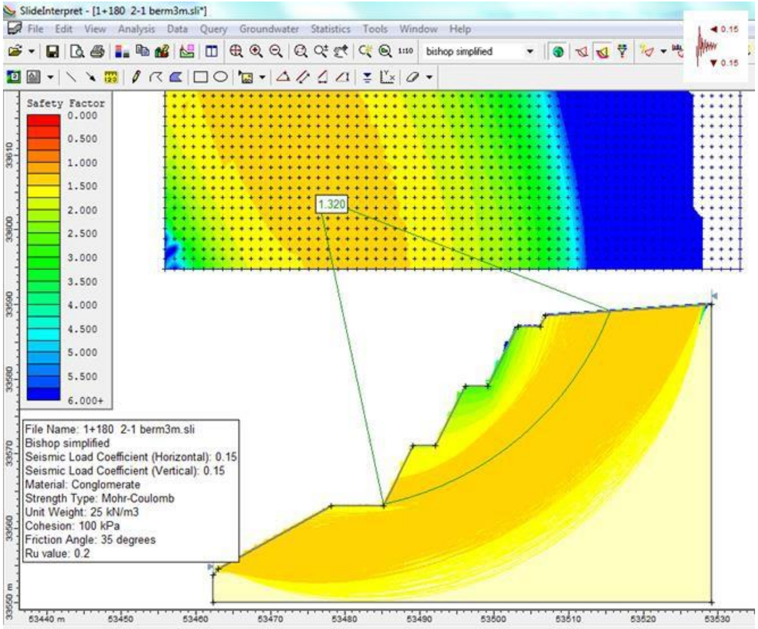


Figure 19. Cross Section of right-side trench km 1+180, Pseudo-Static analysis

- Km 5+720:

Between kilometers 700 + 5 to 730 + 5 of the studied routes, an overpass is found that has a maximum height on the left side of the route and is about 14 meters at around kilometer 720 + 5 and the length of the overpass is about 30 meters. The lithology of the sediments and rocks of this overpass includes about one meter of clayey soil sediments and surface layers and forest soil and under it are silty sandstone sediments with weak cementitious- lime that have pebbles and some parts are conglomerate. These rocks have a uniaxial compressive strength of about 20 to 50 megapascals. The mentioned rock layers in this area have an approximate slope and slope extension of 65°-75° / 350°-360° Bedding: Dip/Dip direction.

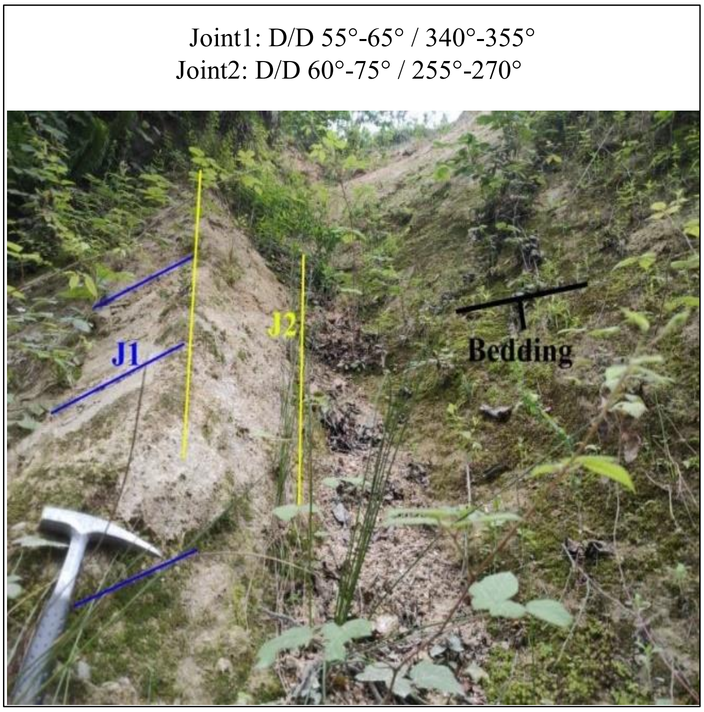


Figure 20. A view of trench lithology and systematic seams and layering

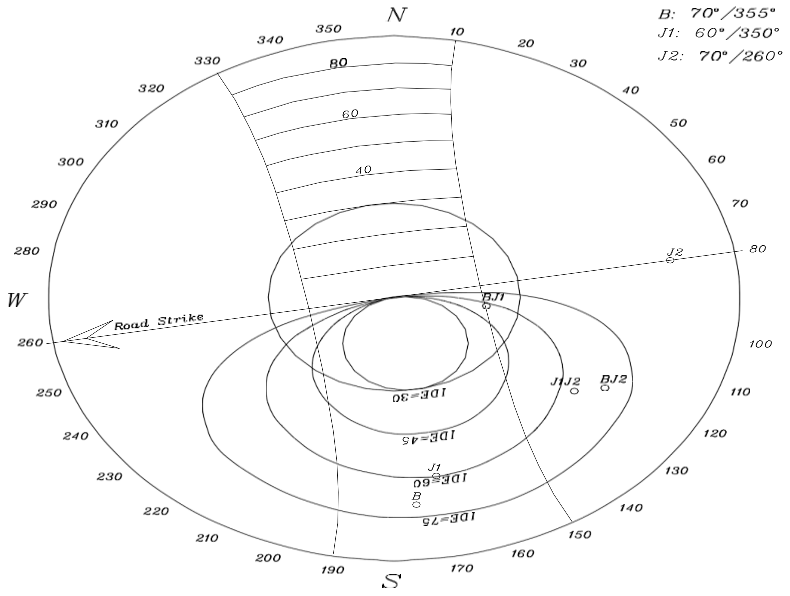


Figure 21. Sliding wedge

According to Figure 21, it can be seen that the poles J1J2 and BJ2 are located in the slip zone and are prone to slip. To stabilize these poles from an instability point of view, a stable slope with a slope of about 63 degrees should be used based on the above kinematic analysis. Also, pole BJ1 is located in the stable cone with a slope of about 30 degrees. Therefore, from the point of view of pole instability, the left wall of the overpass will remain stable with a slope of about 63 degrees. In terms of instability, no instability is observed in the type of overturning. Therefore, it is suggested that the slope of the overpass at kilometer 5+720 be about 60 degrees with a maximum slope of about 75 degrees (2 vertical - 1 horizontal) and be implemented with caution.

According to field observations and similar projects, the internal friction angle of these silty sandstone rocks is mostly about 35 degrees and its cohesion parameter is about 100 kilonewtons per square meter and its density is about 22 tons per cubic meter. The cross-sectional analysis of the left overpass at kilometre 5+72, which has a slope of 63 degrees (2 vertical - 1 horizontal) and has obtained a safety factor of over 1,5 in Static mode with 3-meter berms and an 8-meter step height. The pseudo-Static safety factor is 1.1.

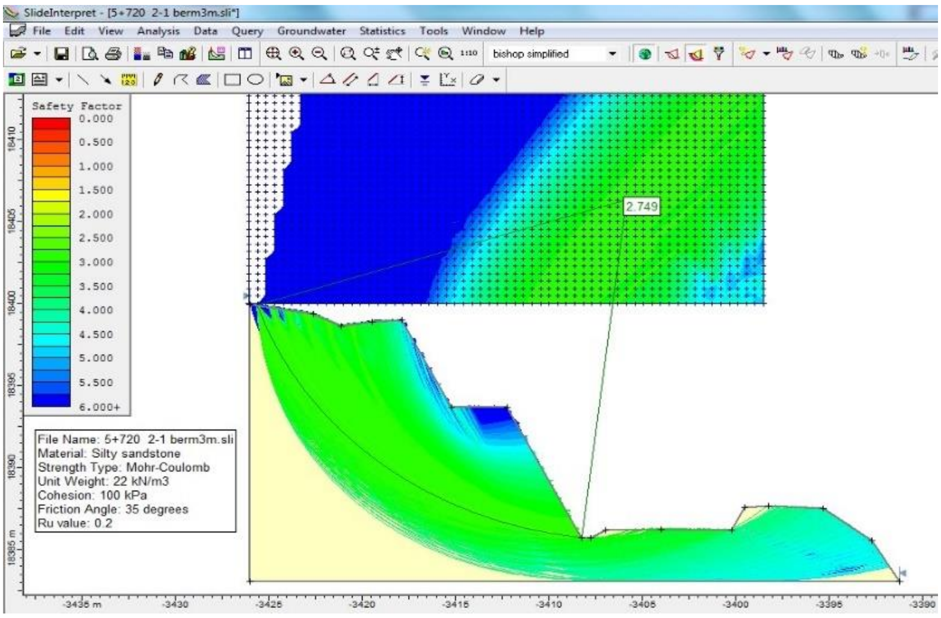


Figure 22. Cross section of left-side trench km 5+720, Static analysis

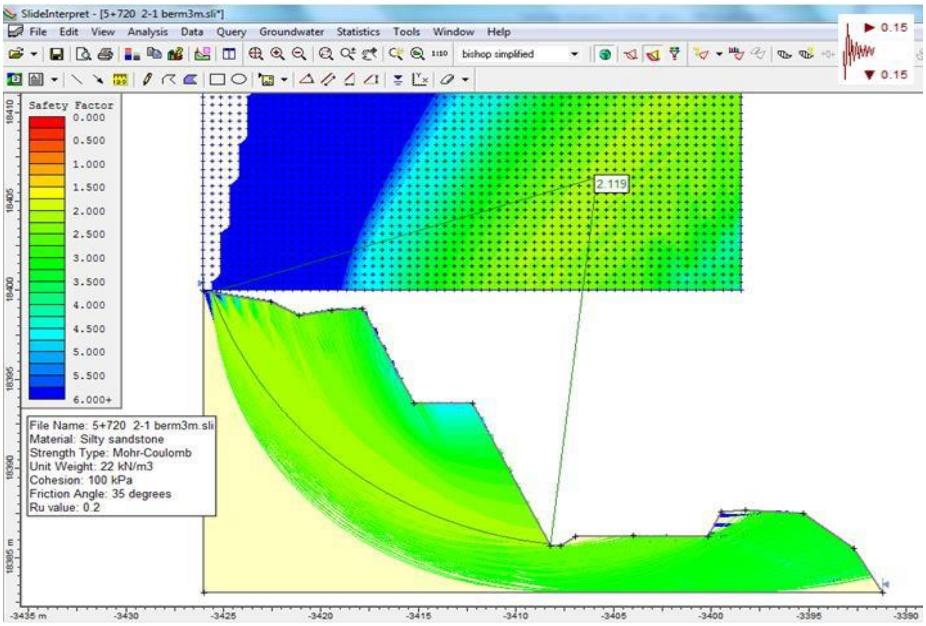


Figure 23. Cross section of left-side trench km 5+720, Pseudo-Static analysis

Based on all the field data and numerical modelling, as well as the topography of the area and road route, and the documents available on site regarding the condition of old culverts and what has happened to the trenches, especially on the valley side due to erosion and landslide, the best method for preserving the stability of the road route and trenches located along it is not to manipulate the existing condition of trenches and to build retaining walls in the necessary locations, especially on the valley side. Also, most of the widening should be done on the valley side due to being located in cross-sectional channels or landslides so that deforestation due to trenching can be prevented and minimum stability can be observed. Furthermore, to prevent road landslides due to improper maintenance of drainage channels and saturation of beds, most of the widening should be done on the valley side by retaining walls.

2.4.1 Retaining Walls

Unfortunately, in the initial estimates of the project, all protective walls were predicted to be concrete without considering the sensitivities of the area and its ecosystem. Fortunately, with the cooperation of all executive factors, these walls were changed to Gabion walls. In this section, we will discuss the types of retaining walls that can be implemented in forests, using available resources and materials as well as retaining walls in the Project.

- Mechanically stabilized earth structures

(MSES) are made by overlapping layers of soil reinforced with wire mesh and or geosynthetic materials (geotextile and geogrids) until reaching the needed wall height. Each layer is built using an appropriately shaped container and is infilled with compacted soil. The main advantages are the simple materials used, low cost and fast construction, minimal foundation preparation (typically), and that they can sustain large loads. The structure can be hydro seeded to look like a typical fill over time. The main disadvantages are the high amount of excavation required, the need for well-skilled operators, and the good quality of filling soil (compaction susceptibility).

Figure 24. MSES Retaining wall.

- Gabion structures

Gabion baskets and mattresses are systems of wire mesh containers filled with stones, rock, or rubble. They are used to build gravity walls that can support slopes and prevent erosion. They are especially useful when the slope angle is too steep or when the slope encroaches into a waterway. Gabion structures can be shaped to fit different situations, such as stepped, sloped, or vertical walls. Gabion structures allow water to drain through them, which reduces the pressure from seepage flows. To avoid losing fine particles from the fill, a geosynthetic filter fabric should be placed between the backfill and the basket. Gabion baskets and mattresses are more flexible and reliable than traditional boulders for gravity wall construction. Gabion baskets and mattresses are made of wire mesh and filled with rocks. They can bend and adapt to different situations, such as when the ground is soft or moves because of frost or other causes. They are good for protecting rivers and streams from erosion, supporting bridges and slopes, and holding heavy loads. Different sizes of gabion baskets can be bought from the market. They usually have a length of 2 m or 4 m, a width of 1 m, and a height of 0.5 m or 1 m. The wall is built by stacking the baskets on top of each other in steps. Gabions are often cheaper than other solutions because they use materials that can be found on-site, such as rubble, broken rock, or concrete. The main drawback of this solution is how it looks. Gabion baskets and mattresses can work together to make strong bridge abutments. Gabions can also help prevent erosion of existing abutments. Reno mattresses are a type of gabion mattress that is used to slow down the water flow and stop the waterway bed from being washed away, especially after a Ford or battery culvert. Mattresses are tied together to make a continuous layer over the waterway bed. Mattresses are 6 m long, 2 m wide, and either 240 mm or 300 mm thick. They are flexible and can fit the shape of the ground. If more erosion control is needed, the mattresses can be covered with concrete.

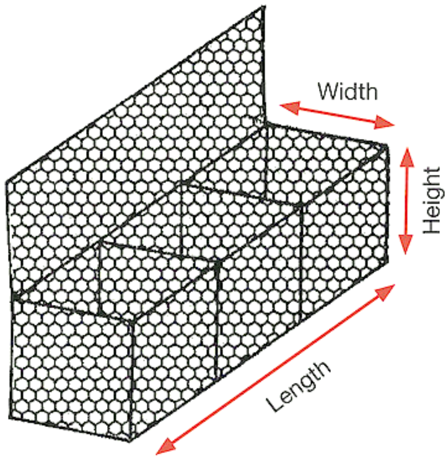


Figure 25. Gabion Basket

Figure 26. Gabion retaining wall km:3+200.

- Timber cribs.

Timber cribs are a traditional retaining wall choice in some parts of the world. The construction components are logs with high natural durability, stones, and spikes. The space between the layers is filled with stones and, where necessary, geotextiles and drainage pipes may also be used. The logs are connected with spikes 20-30 cm in length and 10-12 mm in diameter. The result is a highly water-permeable and cost-effective structure. When compared with a gabion, it is aesthetically more pleasing, and the construction materials are less expensive, but the construction is more laborious.

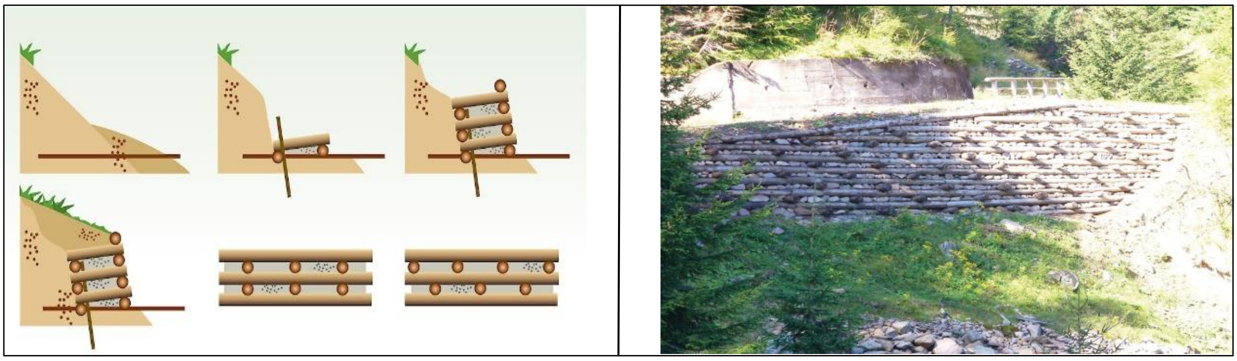


Figure 27. Timber crib.

- Timber cantilever pile wall.

Another common retaining wall design possibility is using vertical poles fixed in the ground that sustain horizontal logs or lumber containing the backfill soil. These are common outside forestry in New Zealand. The design should consider the bending resistance of the poles used and the pole depth into the soil. A rule of thumb is that the depth of the poles should be as the wall is high. Cantilever pile walls are a low-impacting solution with the major advantage being a low amount of excavation. However, on the ground with bedrock or soils with larger rock components, it may be difficult to drive piles to the necessary depth and other options need to be considered.

Figure 28. Timber pile wall.

It is most important to determine the source of factors influencing slope instability to be able to design proper control and rehabilitation measures. Very often a single measure may achieve the desired results but sometimes it may be necessary to combine measures to restore the stability of the slopes. For instance, on a seepage slope, it may only be necessary to drain off the water with open ditches or stone-filled drains. On other occasions, it may also be necessary to revegetate the slope to fix the slope surface because vegetation would not come back at all or it would take too long a time, and a retaining wall would be required. In a mountain road project in the USA (Idaho), it was noted that 60 percent of the surface erosion occurred within one year of the disturbance of the slope; thus, it is important to stabilize slopes at once, or shortly after the construction of a road.

Since old times in the region, the use of Gabion has been common for the stability of the slopes; it's very compatible with the ecosystem of the region. It's also cost-effective because we have a large volume of retaining walls on the road, and a principal issue in any Project is balancing the costs. For all these reasons we chose Gabion retaining walls for our Project.

Figure 29. Retaining wall construction km 7+500

3. RESULTS AND DISCUSSION

Given that the main goal of improving this road is to transfer raw coal from the Goliran mine and increase efficiency and reduce transportation costs alongside its effects on the people of the region, it is clear that heavy machinery traffic with the load on roads has destructive effects on the surface of the road and other structures along the route. Therefore, quality, durability, and operability as well as environmental issues are among the fundamental issues in improving and widening this road. Accordingly, observing all engineering principles while considering special regional issues such as reducing environmental impacts is one of the priorities of the employer and contractor and we have not spared any effort or effort to achieve the lofty goals of the project and help even a small step towards economic growth. Given that the project is still in its implementation stages, it is hoped that in the future, other research and articles that highlight the fundamental principles and benefits of the project will be prepared and compiled. Given the two rainy seasons and harsh winters in the highlands of the region, fortunately, no damage was done to the road body or route culverts. The ditches had an incredibly superior performance in collecting and discharging surface water throughout the route. It should be noted that during the entire rainy season, ditches and culverts were cleaned for free passage of surface water and prevention of flooding when necessary. Also, traffic on the entire length of the road has been improved compared to before and is now flowing smoothly and without problems and at high speed. This is a real model for testing and evaluating the performance of the improved route. It is worth mentioning that throughout the length of the road, due to its narrow width and simultaneous use of mining compressors, private cars, and all road construction equipment, and due to the lack of an alternative route, the route was never closed. This is a real model for evaluating the performance of the road and good working.

4. CONCLUSION

As a result, it is clear that all Drainage and Stabilizing implementations work together and it is impossible separating them in this case. It means that, if these types of roads built or reveal, it is needed to build Ditches, Culverts, and Retaining walls to be in harmony with each other. The drainage structures on a sample forest road should be visited and dredged periodically of course before Rain to ensure their proper functioning. Planning of all kinds of drainage structures used on forest roads should be done appropriately. Based on the calculations made as a result of field studies, measurements, and observant ions are especially important in determining the type, size, and location of the drainage structure. Drainage structures must be placed on the road route at an angle of 30 ° - 45. This will improve system function; it should not be placed perpendicular to the road. Because erosion and accumulation of sediment can be observed in the place of structures, that are placed perpendicular to the flow direction. A 3-6% longitudinal slope should be applied to the interior of the culverts to prevent sedimentation inside the culvert. Particular attention should be paid to material selection for constructing drainage (Ditches and Culvers) and retaining structures.

Have to use natural materials and avoid using concrete especially exposed or as the cover of ditches. While deciding the places of culverts, the grades of fields and roads should be considered. When the grade of the entrance is higher than the exit, it surely causes sediment and water accumulation inside the culvert. Of course, most of the mountain routes drained into the valley and it's important that the culvert outlet is placed on the retaining wall and the drainage route stabilized. A cheaper way of stabilizing channels and outlets of water crossings is to provide rook riprap which in most cases gives satisfactory results.

The landings should be prepared in size of 90-100 cm before the entrances of culverts by Rock fill materials. Thus, sediment coming with water from dip drains will be massed on these landings and cleaned more easily during periodic maintenance. Also, bracket walls at the entrance are necessary to prevent erosion on the roadside. For each term, before and after forest field works, entrances, and exits of drainage facilities should be cleaned with the help of an excavator or laborer. When placing the drainage structures in the designated area, the foundation excavation of the structure should be made up of bedrock. If the foundation is not placed on solid ground, the culvert remains high and the water that should pass through the culvert can flow through the foundation of the culvert or should be built the foundation with the cutoff wall. The foundation or the first step of the Retaining wall should be placed on a Solid and reliable platform, at least 2 meters of the Gabion with a height of more than eight meters should be buried, and the inclination of the structure is toward the trench. It is recommended that the minimum width of the floor is equal to 60% of the height of the wall. Considering that a gabion is a flexible object, it adapts well to the forest environment, and in case of any settlement, it can continue its duties without losing its efficiency, and it’s possible to restore and increase the height of the gabion wall. It's important to Choosing the right wire mesh according to the applied pressure and the use of restraining wires to strengthen the basket, as well as ensuring the complete elongation of the wires and mesh in a way that prevents any movement of stones, is one of the main factors in the construction of a gabion retaining wall that can have the necessary durability and stability.

Finally, in Projects in the forest or protected areas, the cooperation and consensus of forestry and natural resources officials are remarkably effective to make the implementation of the Project as easy as possible.

Figure 30. Km: 4+950 during construction

Figure 31. Km: 4+950 after construction and backfill

Figure 32. Retaining wall seen from the mountain peak, Km: 6+050

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Declaration of Competing Interest

There is no conflict of interest in this study.

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