Landslide for Education; A Case Study from the Mitigated Landslide at the Kahagalla, Haputhale

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Abstract— *This study focuses on the Kahagalla landslide mitigated site, an exemplary landslide mitigation and management project. The purpose of this study is to provide valuable insights from the Kahagalla landslide mitigated site, which can be utilized for educational purposes in the fields of geography, geology, civil engineering, and disaster management. This case study is a qualitative study that used field observation as the primary data collection method and relevant documents as the secondary data collection method. Data were analyzed using the thematic analysis method. The case study analyzes the background of the landslide site, the measures taken for mitigation, and the overall success of the project. It also highlights the importance of this site to use as an educational site. The results reveal that the Kahagalla landslide site can give proper knowledge on landslide education. Further, the site is rich in different landslide mitigation methods and accessible. So, the recommendation is to use these kinds of available sites in Sri Lanka to enhance the practical knowledge of education.*

Keywords— **Landslide, Education, Mitigation Site, Countermeasures.**

I. INTRODUCTION

Sri Lanka is a well-known country experiencing landslide disasters which are the commonest. Though landslide disaster frequently occurs, awareness among the people is limited, hence every year some communities are affected. It is well noted that the number of cutting failures has been increasing recently in the country indicating the lack of knowledge in slope stability. Hence awareness or education in landslide hazards and disasters must be well established in the country.

When giving education on disasters, its practical engagement should be more focused. The importance of education is not only book learning but also fieldwork to give students valuable real-world experience (Hirota,2015). Further, field works allow a "deep study approach" instead of a "surface approach" (Molderez and Fonseca, 2018). So, the field visits along with the practical sessions should be incorporated more in the education system.

Landslide education is available in different fields such as geography, geology, civil engineering and disaster management. The education on landslides can be conducted through field tours to such sites. The best locations should be safe sites where no further sliding is ensured. Such sites are the mitigated landslides. Mitigated landslides show the past sliding and also the way of mitigation, hence such sites are safe sites for education. If the site is very close to a major road with easy access, that can be an ideal location for promoting landslide education.

The Kahagalla earth slip which was a unique landslide first occurred in 1957 (Wijesinghe et al, 2016). Kahagalla landslide was classified as a creep type of landslide, which has a slow downward movement of soil and debris materials. The main landslide body extends about 650 m on a gentle slope. However, some community buildings and infrastructures exist just below the landslide, while a stream is drained adjoining the landslide. Badulla Colombo road had been continuously damaged annually during the rainy seasons due to the movements of the slide. To avoid this impact, the area was protected by landslide mitigation methods.

This study will discuss the possibility of using Kahagalla mitigated landslide site for educational purposes.

II. METHODOLOGY

Data collection and data analysis methods are discussed in this section.

Field observation as the primary data collection method has been used to observe the site and identify the countermeasures of the site. Further, GPS (Global Positioning System) points have been collected to identify the absolute location of the site. Furthermore, published papers have been used as the secondary data collection method.

The above-collected data was analysed using the thematic analysis method. When considering the process of the

analysis, all the collected data were prepared for analysis by putting memos and comments. Then as the second step of the process of analysis, read through the data. Later on, the data was coded. The themes were generated based on the codes.

"Location of the site", "Landslide Education and the Kahagalla Site" and "Benefits of Using Kahagalla Site for Education" are the themes that could be identified through thematic analysis.

III. RESULT AND DISCUSSION

The results and discussion section has been organized according to the themes identified by the thematic analysis. These results will reveal the valuable insights and lessons learned from the Kahagalla landslide mitigated site, which can be utilized for educational purposes.

G. The location of the site

Location is one of the important factors when considering a site for an educational purpose because accessibility is crucial. The absolute location was identified by taking the GPS coordinates of the site at the field observation, as shown in Figure 1.

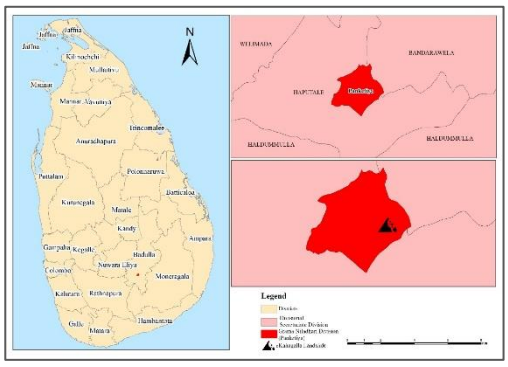

Figure 1. Map of the site
Source: Prepared by the Author, 2023

This site is in the Panketiya Grama Niladhari division of the Haputhale Divisional Secretariat Division of the Badulla District of Uva province.

The Haputale-Bandarawela road runs across the toe of the landslide. Further, there is a village at the bottom of the landslide site. Google Earth map has been used to identify the relative location as clearly shown in figure 2.

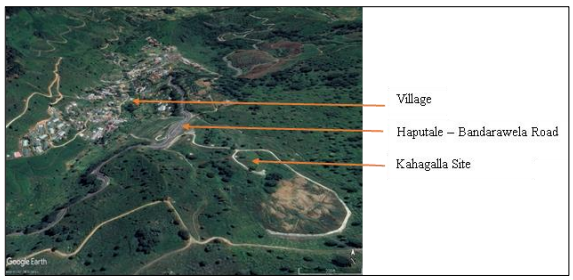

Figure 2. Relative location of the site
Source: Prepared by the Author, 2023

This location is feasible to access. Many educational trips are organized to hill country and this site also can be accessed on the way to other destinations.

H. Landslide Education and Kahagalla Site

Landslide education discusses topics such as the definition of landslide, types of landslides, features of landslide, causes of landslide, identifying landslide hazards, identifying landslide risk, impacts of landslide and landslide mitigation among many others. Even though teacher-centered basic knowledge should be given to get the approach to the topic and explain the theories, a case study can be used even from the beginning in landslide education.

In education, scientifically proven information is critical. When considering the Kahagalla landslide, information with a scientific base is available as published papers and documents from the National Building Research Organization (NBRO) which is the responsible organization for landslides.

The nature of the Kahagalla landslide can be identified using the published papers. Kahagalla landslide was slowly moving towards the toe area (Wijesinghe, 2016). The slop was specified by sinking soil, dominated by colluvium and residual components, at the scar area due to calc-silicate solution cavities. Further, the circular-type rotational failure in the middle and moving soil at the toe area could be found. The slip surface which was caused by water pressure in pores due to the infiltrated water and water in the solution cavities was located at a depth of 15.8m. The subsurface of the Kahagalla slope mass was formed by the breakdown of underlying layers of garnet, biotite, sillimanite, gneiss, and an impure crystalline limestone layer that existed towards the head scarp (Amarasinghe, 2022). The studies highlight the role of weak soils in the development of the slip surface, the influence of solution cavities in the underlying marble bedrock on the development of high pore water pressure, and the soil weakening character of the relict discontinuities of the underlying rocks of Kahagalla landslide. The triggering factors have been identified as surface water, groundwater, and erosion at and around the toe by the streams limiting the landslide area (SCRIBD article). For these triggering factors, the topographic condition of this area is significant because the rainfall in the surrounding area flows into the site as forms of both surface water and groundwater.

Moreover, the works of the literature revealed the structure of the site. This site can be categorized into four blocks (Karunawardena, 2021) as shown in figure 3.

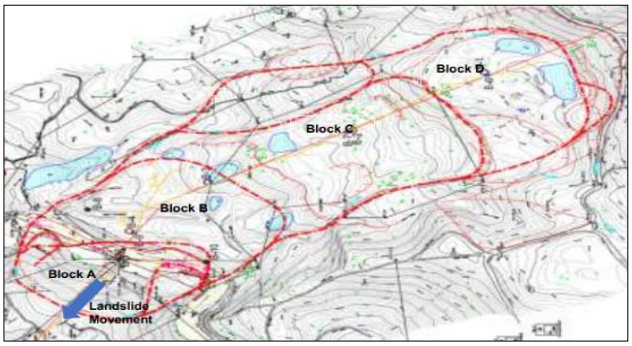

Figure 3. Blocks of Kahagalla Landslide
Source: Karunawardena et al, 2021

Block A was a highly active part of the site and it was located at the bottom of the landslide across the A016 road. Small water pools were observed in block B after heavy rain. Further, the height of the scrap was about 3m the main part of the block was gentle, but had disturbed the slope. Block C consisted of a scrap of about 5m and the bare ground around the scrap. Block D had a steep slope along with the estate road corresponding to the head scarp. Spring water was observed along the road and some water pools & surface water flow have been observed in this block.

Further field observations prove that the Kahagalla landslide site is a suitable location for identifying countermeasures for landslides. In disaster risk reduction measures structural and non-structural measures are considered. These structured disaster risk reduction measures can be divided into two engineering and non-engineering measures. In the Kahagalla landslide site, these engineering and non-engineering structures can be clearly identified. The nature of the natural conditions and their applications should be considered before applying these countermeasures. This is what especially teaching in higher education, the practical scenarios. This site can be used as one of the real-world applications for explaining landslide disaster risk reduction measures in fields such as geography, geology, civil engineering, and disaster management.

Countermeasures on the site are important because those are the more attractive features on the site. Those can be identified as monitoring and mitigation methods.

Water gauges as shown in figure 4 are used to monitor underground water levels, which helps to reduce the risk of landslides by providing information about how the water level fluctuates.

Figure 4. Water gauge
Source: Photo taken by the Author, 2023

The Drainage wells in this site were designed as a cascading system as shown in figure 5. This system aids in the withdrawal of water from the hill area to the valley, lowering the groundwater level.

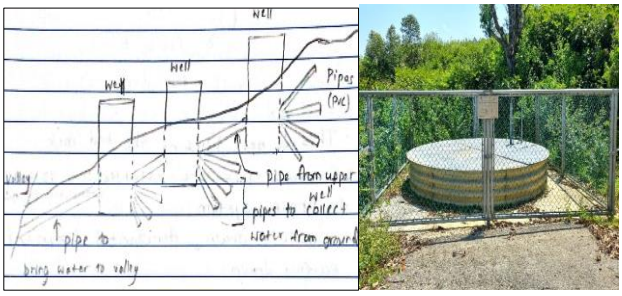

Figure 5. Drainage Wells
Source: Drawn and the photo taken by the Author, 2023

For this drainage well system, specific pipes have been used to transport water from one well to another by collecting water from the soil.

Other mitigation techniques that have been used on this site are soil nailing and ground anchoring. Ground anchors have been installed just above the road as part of the soil-strengthening strategy. Concrete slabs have been erected to connect the anchors. This aids in the prevention of shallow landslides, which cause frequent damage to the road. This structure attracts road travellers because it provides a view of the site as shown in figure 6.

Figure 6. Ground anchors
Source: Drawn and the photo taken by the Author, 2023

Another method that has been used for mitigating the landslide in this location is installing a drainage system as in Figure 7. In this location, cutoff drain, horizontal drain, and surface drain could be identified. Surface drains were

constructed to intercept and divert surface runoff, reducing infiltration and diverting surface water away from the landslide.

Figure 7. Drain System
Source: Photo taken by the Author, 2023

The drain system has been implemented to remove the surface water when it is raining. This has been constructed in a sufficient way. The reason for this is that the drains are well connected to each other.

A bridge also has been constructed at the site as one of the mitigation methods as shown in Figure 8.

Figure 8. Drain System
Source: Photo taken by the Author, 2023

This bridge has been constructed using a honeycomb structure that is light in weight. Bubbles in the concrete were used to make this structure lightweight. It denotes the presence of gas bubbles in the concrete. Despite the fact that this is a costly method, it reduces the structure's weight. Further soil nailing has been used just above this.

Another mitigation method that can be identified at the toe of the landslide and the crown of the landslide is a method of soil bioengineering. Plants have been planted in these locations. However, when doing these things, their focus has been on the weight on the ground, which should be less to avoid pressure. As a result, bushes have been planted at the landslide's crown as shown in Figure 9 because the weight on the land is less. Trees have been planted at the foot of the landslide to increase the weight of the land, allowing it to bear the soil and prevent erosion. The plants used for this method should have higher evaporation capacity, a strong root system, and be easy to maintain.

Figure 9. Bushes on the site
Source: Photo taken by the Author, 2023

Furthermore, earth removal at the landslide's head and counter embankment construction at the landslide's toe were completed to balance the force and improve the landslide's overall stability.

To stabilize the landslide, the countermeasures which have been discussed were designed and built on the site using Japanese technology. So, this site can be used as a knowledge dissemination center.

By examining these kinds of real-world applications and successful landslide mitigation projects, students can gain practical insights into the challenges, strategies, and outcomes associated with mitigating landslides.

I. Benefits of Using Kahagalla Site for Education

There is a significant number of landslide mitigation sites in Sri Lanka but the Kahagalla site can be emphasized as the only site with different landslide mitigation and monitoring measures in Sri Lanka.

Enhancing technical knowledge is very important in education. Landslide mitigation sites showcase the application of engineering techniques and technologies specifically tailored to mitigate landslide risks. By studying this site, students can gain a deeper understanding of geotechnical engineering principles, slope stability analysis, soil stabilization methods, and other technical aspects of landslide mitigation.

Further, studying landslide mitigation sites such as Kahagalla site allows students to understand the interdisciplinary nature of addressing landslide risks. They can explore how different disciplines contribute to planning, designing, implementing, and monitoring mitigation measures.

Moreover, Kahagalla landslide mitigation sites offer valuable lessons in risk assessment and management. Students can learn how to identify landslide-prone areas, assess potential risks, and develop strategies to minimize

the impact of landslides on communities and infrastructure. They can explore techniques such as slope monitoring, early warning systems, and land-use planning to reduce vulnerability to landslides.

Community engagement and resilience are also one of the important areas in landslide education. Landslide mitigation projects often involve community engagement and participation. This Kahagalla project is also the same. Studying this site helps students understand the importance of involving local communities in decision-making processes, raising awareness about landslide risks, and building resilience. Students can explore methods for effective communication, community empowerment, and the social dimensions of disaster management.

Environmental considerations should be emphasized in learning. These landslide mitigation sites prioritize environmentally friendly approaches to minimize ecological impacts. Soil bioengineering is an example of this. Students can learn about sustainable engineering practices, the preservation of natural ecosystems, and the integration of ecological principles into landslide mitigation strategies.

Policy and governance are significant sections that should be focused on in landslide education. Studying landslide mitigation sites can shed light on the policy and governance frameworks that govern such projects. Students can examine the role of government agencies, regulations, and standards in ensuring effective mitigation measures. They can also explore policy challenges, funding mechanisms, and the importance of long-term planning and maintenance. Kahagalla landslide is one of the sixteen proposed mitigation sites under the Landslide Disaster Protection Project (LDPP) in Sri Lanka (Wijesinghe et al, 2016) and many stakeholders such as Japanese International Cooperation Agency (JICA), Road Development Authority (RDA), Oriental Consultants Co, Ltd (OC),Kokusai Kogyo (KKC), Engineers and Architects Associated Private Limited (CEA) and National Building Research Organization (NBRO) were involved.

By studying landslide-mitigated sites, students gain a comprehensive understanding of the complex factors involved in mitigating landslide risks. Kahagalla landslide site also has the capacity to provide knowledge to the students. This knowledge can contribute to more effective and sustainable approaches to managing landslides in the future, thereby reducing the potential for loss of life and property caused by these natural hazards.

J. Conclusion

By studying the Kahagalla landslide mitigated site, students and professionals can gain valuable knowledge about the landslide, landslide mitigation strategies, their implementation, and the importance of comprehensive planning and monitoring. This case study serves as a practical resource for educators and researchers to identify the landslides with the aim of enhancing understanding and preparedness for landslides in vulnerable areas.

K. Recommendation

This study explains the capability of the Kahagalla landslide mitigation site to be used for educational purposes. So, the ultimate recommendation is to use these kinds of available sites in Sri Lanka to enhance the practical knowledge of education. Further, how to use this site as an educational site should be considered. When the Kahagalla landslide site is used as an educational site, different stakeholders like state and local governments, private land owners, media, university students and school children can be identified. Analysing stakeholders and identifying their roles and responsibilities in using these kinds of sites as educational sites are recommended for future research works.

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