

Natural and Anthropogenic Impacts on Khanzad-Banaman Castle, a Geological-Cultural Heritage in Erbil-KR/ Iraq

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Abstract: This study highlights the relevant categories of heritage and proposes strategies for prioritizing the protection of geological and cultural heritage, focusing on the importance of geoconservation and geotourism as tools for preserving geoheritage in a Castle, which is under increasing threat from climate change and anthropogenic impacts. It also assesses unique geomorphological landforms and cultural heritage sites affected by climate change and anthropogenic impacts. The case study focuses on Khanzad–Banaman Castle, a geological-cultural heritage site built in the 16th century and located atop a geological ridge of aesthetic value. The ridge consists of sandstone and claystone belonging to the Miocene Injana Formation. Engineering, geological, and anthropogenic surveys were conducted. The area is situated on the southwestern limb of the Permian anticline, and the rock slopes are affected by landslides, including rockfalls, toppling, wedge failure, and creep. These instabilities result primarily from discontinuities within the rock beds. Anthropogenic activities have further increased slope instability.

Keywords: Cultural heritage, geoheritage, geosite conservation, Iraq, Khanzad-Banaman Castle, natural and anthropogenic impacts, rock slope stability.

Introduction

The United Nations Educational, Scientific and Cultural Organization (UNESCO) classifies heritage into either cultural or natural heritage (CNH). Cultural heritage reflects a broad range of values and includes artefacts, monuments, groups of buildings and sites, and museums. Natural heritage refers to natural features, geological and physiographical formations, and natural sites of value from the point of view of science, conservation, and natural beauty (UNESCO 1972, 2009).

Cultural heritage preservation from natural and anthropogenic damages is a crucial point in the management of the heritage (Lollino & Audisio, 2006). The importance of humans as geomorphological agents is indicated by the fact that at least one-third of the earth's continental surface of 149 million km² is a scene of direct or indirect anthropogeomorphological activity (Rozsa, 2007). Cities have ecological footprints that are orders of magnitude larger than their physical area, exerting heavy impacts also on distant peri-urban and rural ecosystems. Cities are home to 4.4 billion people — well over half of humanity. This figure is projected to reach 6.7 billion by 2050 (IUCN, 2023). Over the past

twenty years, reconstruction activities and infrastructure development have expanded and modernized both within cities and in surrounding areas, including the construction of roads and tunnels connecting urban centers. The amount of materials on the earth's surface moved by various anthropogeomorphological activities is the most quantitative value for describing human impact on the landscape (Rozsa, 2007). The rock slope stability along major roads in cities and mountain areas has been studied by many researchers, focusing on natural factors assessed the precipitation-related climate risk of natural and cultural heritage (Hussain, 2014; Wang et al., 2022).

This study was carried out to show the results of both factors on a geological-cultural heritage area. The 1972 UNESCO World Heritage Convention is the principal instrument for identifying and protecting, for the benefit of current and future generations, the outstanding natural and cultural heritage of the world, and encouraging international cooperation for its conservation. The World Heritage Committee has recognized this emerging threat and responded at its 29th session by launching an initiative to assess the impacts of climate change on World Heritage and

define appropriate management responses (Augustin, 2007).

Iraq is a unique country with a richness of diverse topography, geology, heritage, culture and biodiversity, especially the north of Iraq, which has various cultural heritages and geological diversity

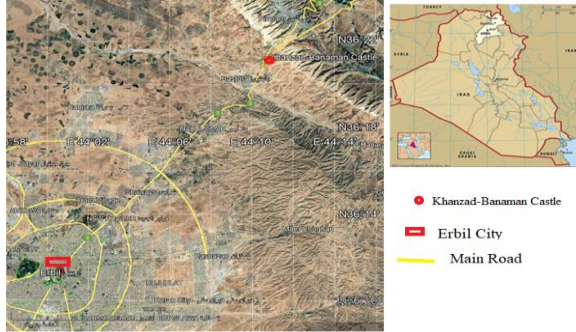


Fig. 1 Location of study area (Google Earth, 2025).

(Hussain, 2022). Khanzad-Banaman Castle is a cultural heritage site and a geotourism attraction, located in the district of Erbil city. (Fig.1). Erbil governorate is located in the northern part of Iraq. The city is one of the world's most ancient, dating back to as early as 2300 BCE. Erbil is famous for its geodiversity and cultural heritage. It is important to determine the impact of climate factors on the cultural heritage, to develop suitable conservation strategies and create projections for the future (Marius et al., 2017). The history of this castle dates to the era of Sulieman Beg, the prince of the Soran Emirate in the 16th century, under the rule of Princess Khanzad and her brother, Prince Suleiman Beg (Ghafour, 2021).

It was used as a military base. The castle's name relates to Khanzad, which is the name of the "Kurdish Warrior Queen," who is commemorated and referenced in various Kurdish songs and poems. She ruled the Soran Emirate after her brother, King Mohammed, died after being poisoned. Khanzad-Banaman castle is a military fortress located in the north of Erbil city. Mir Muhammed built it in the late 1340 AH- 1824 AD (Ghafour, 2021). The castle is rectangular in shape and consists of two floors made from large stones and plaster (Fig. 2).

Khanzad-Banaman Castle is 40 meters high, and it has four round-shaped towers with many windows. The area of the castle is 15.5 meters long and 10.5 meters wide. Although the Kurdistan Regional Government reconstructed it in 2005, unfortunately, the castle suffers from neglect and a lack of management to protect it from landslides and loss of its cultural value, and to preserve the cultural heritage and the safety of tourists. (Fig. 3). The conservation of CNH is a way of

connecting the knowledge of past, present, and future generations, and it throws light on our understanding of human and toponymic identities (Estibaliz et al., 2024).



Fig. 2 Left - The statue of Khanzad, the princess of the Soran Emirate. Right - The cultural heritage of Khanzad-Banaman Castle (Zhyan Media, 2018).

This study aims to indicate the anthropogenic geomorphology on the cultural heritage, in addition to studying the natural processes, by using the Khanzad-Banaman castle as a case study. The Castle is built on a hill on the southwestern limb of the Permian anticline. Landslides can directly threaten the integrity of sites located in mountainous regions and relatively high relief areas (Di Luzio et al., 2019; Tunusluoglu and Zorlu, 2009). Banaman is situated about 20 km from Erbil city. The castle's height is about 50m above the ground surface and sits on the top of a hill between two roads, about 750 m. a.s.l. The castle has four round towers at each corner, made of rocks and gypsum. It is a unique archaeological site. The significance of cultural heritage is that it plays a crucial role in human lives and history, influencing the values, beliefs, sense of belonging, identity, historical perspective, tourism, and eventually economic growth and cultural diversity (Stephenson, 2023).



Fig. 3 Interior and exterior of Khanzad-Banaman castle before the Kurdistan Regional Government reconstruction. (Zhyan Media, 2018).

Geological Setting

The study area is within the high folded zone. Khanzad-Banaman Castle is located on the southwestern limb of Permian anticline, which is a symmetric deepening steep to the southwest. The anticline is composed of Cretaceous to Tertiary layers. The area presents a spectacular landscape, characterized by unique geomorphological features which possess scientific, educational, cultural, and aesthetic value. The study area is a mountainous region within the high folded zone of Iraq, which is marked by a series of folds trending NW-SE. This zone is formed by long and narrow anticlines separated by wide and shallow synclines (Fig. 4). The geology of the study area consists of sedimentary rock outcrops in homoclinal beds formed from different lithologies of beds, which consist of the oldest formations: Pilaspi, Fatha, Injana and Al-Mqdadia formations (Jassim and Goff, 2006; Burtcher et al., 2012).

The wide-separating formation in the study area is the Injana Formation of Miocene, which consists of a succession of sandstone layers alternated with mudstone deposited in fluvial continental environments, rich in different sedimentary structures. Petrographically, the sandstone is composed of carbonate rock fragments with a high percentage of quartz, mostly poly- and monocrystalline. The depositional environment is characterized by different types of rivers that transport and deposit coarse sand through high-density currents, as well as fine-grained sediments—primarily mud—through low-density currents. The total thickness of the Injana Formation is about 110 meters. The lower contact between the Injana Formation and Fatha formation is identified by the appearance of the sandstone layer, and the conglomerate layer of the Al-Mqdadia Formation indicates the upper contact. Khanzad-Banaman Castle is located on the Injana Formation (Fig. 5).

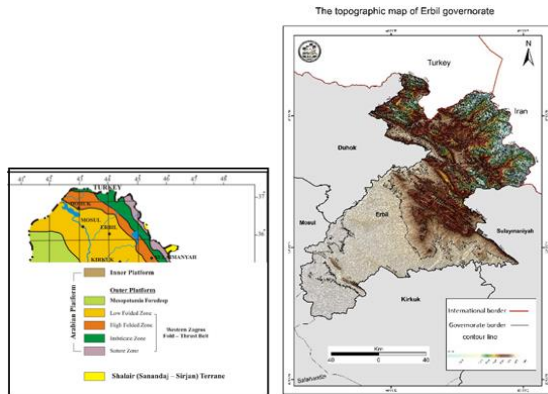


Fig. 4 Tectonic division map of the northern part of Iraq (Fouad, 2012).

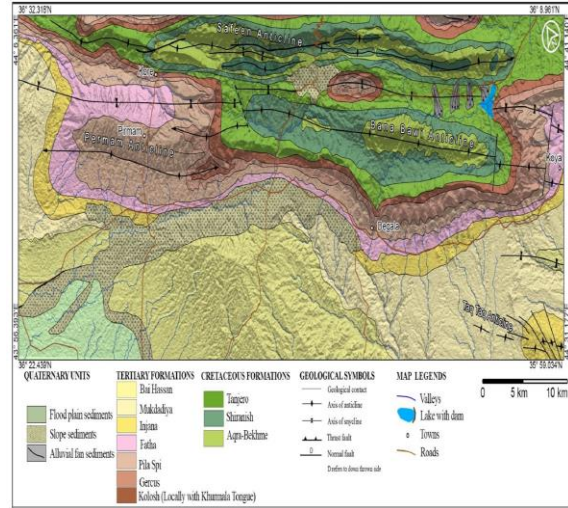


Fig. 5 Geological map of the study area (Ala, 2023); (Sissakian and Fouad, 2015).

The Geomorphology of the area is formed of various ridges and valleys distributed in the southwestern limb of Permian anticline with different rock types . This site represents areas with a wide variety of geographical, geological and geomorphological elements along with tectonic processes and history. The area is common for a dendritic drainage pattern within valleys and mountains.

Bastura Valley is the major valley in the south of the geoheritage hill with a subsequence stream type. The limb slopes show various types of ridge including cuesta and hogback ridges. The geological heritage is located on a hogback ridge, which created a unique tourist attraction with an elevation of 840 m above sea level. The topography of the area is a hill in the southwestern limb of Permian anticline. Its height above the ground surface is about 40 m. (Fig. 6).



Fig. 6 Top of the hill, which is a unique tourist attraction, photo taken in June 2021.

Materials and Methods

Monitoring and analyzing the topographic changes affecting the stability of the Banaman Castle area were conducted based on geological, geomorphological, and engineering geology studies of the geo-cultural heritage site, accompanied by an assessment of anthropogenic activities. Various geological surveys were carried out in the study area during 2022–2023. These surveys included determining the dip and attitude of bedding planes and slopes, as well as identifying the lithology of the exposed rock units. Erbil Governorate is unique in terms of its geodiversity elements, which are characterized by structural features, ridges, cliffs, gorges, caves, and other geomorphological forms (Hussain, 2022).

Three sites were selected for rock slope stability assessment, by using the stereo projection analysis with Dips software v6.008, the attitude of the beds, joints, and the slope used to produce stereographic projections and with the Kinematic analysis. The stability of the castle slopes was evaluated by analyzing the impact of topographic modifications made to create access pathways to the castle summit. In addition, the geomorphological impacts of anthropogenic activities were also assessed by analyzing the changes in the hill morphology and the increasing instability of the hill slopes.

Results and Discussion

Geomorphological Impacts

Natural processes and human-induced geomorphological activities affect the stability of rocky slopes at the three stations (Fig. 7).



Fig. 7 Location of the stations showing the most affected area.

Station No. 1: This station is located at the start of an irregular pathway made on the hill foot consisting of red claystone of the Injana Formation with a thickness

of 28m, overlaid by a sandstone bed, dipping $40^\circ/220$. The attitude of the slope is $70^\circ/130$ with a width of 7m, height variable 4-8 m, and type parallel and discordant. The discontinuities are $90^\circ/130$, $80^\circ/215$ and $80^\circ/240$.

Evidence of rockfall is pointed out in Figure 8). From the Kinematic analysis the following failures occurred are concluded mass-wasting type creep of claystone with several rill erosion signals on the slope surface with the direct and flexural toppling of sandstone rocks and planar and wedge sliding failure (Fig. 9), which resulted from the weathering and erosion processes of the claystone below sandstone beds causing the detached blocks of sandstone bed topple down on the slope surface.

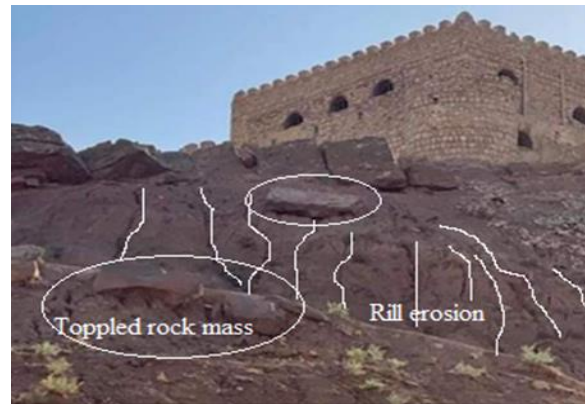


Fig. 8 Southwest slope view of station 1.

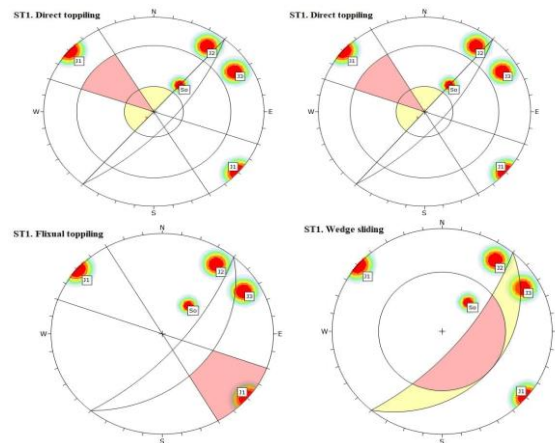


Fig. 9 Kinematic analysis of station 1.

Station No. 2: The slope consists of a sandstone bed of Injana Formation with a 25-50 cm thickness and red claystone beds laid under the sandstone bed of

about 6 m. The slope width is about 10 m, height 4m, with an attitude of $40^{\circ}/200$. The attitude of the sandstone bed is $36^{\circ}/217$. The slope type is a parallel slope and concordant. The sandstone bed is densely fractured with three sets of joints $80^{\circ}/130$, $90^{\circ}/215$, and $90^{\circ}/240$ (Fig. 10). Using the stereo projection (Kinematic Analysis) concluded that there are direct and flexural toppling of sandstone rocks and planar and wedge sliding failure (Fig. 11).



Fig. 10 Station 2 shows the systematic and nonsystematic joints (E view).

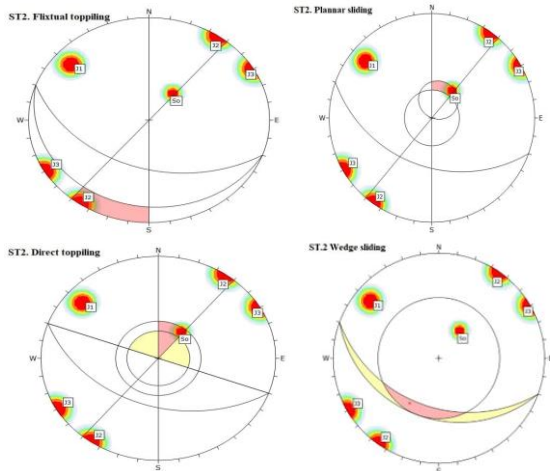


Fig. 11 The Kinematic analysis of station 2.

Station No.3: This station consists of interlayers of sandstone beds and mudstone, dipping $35^{\circ}/195$. The slope is variable in the upper part, is 30° to a vertical rock slope direction 104 in the lower part of the slope, 17 m high and 12 m wide. The sandstone layer is fractured by discontinuities with three sets of joints; the first attitude is $80^{\circ}/128$, the second is $90^{\circ}/238$, and the third is $90^{\circ}/214$. The resulting collapse is a rockfall due to the presence of discontinuities. The cohesion

between discontinuities is zero, allowing rock masses to fall down the slope under their own weight. The expected collapse are toppling due to the presence of clay layers that offer weak resistance to the rock masses above them, as well as the presence of fractures surrounding the rock masses, which leads to toppling of the sandstone bed and creep of claystone from the slope surface to the ground surface, where the main road is, the Kinematic analysis shows the following failures: Plane sliding Wedge sliding Flexural toppling direct toppling. (Figs. 12 and 13).



Fig. 12 Rock cliff holding on the top the historical castle of cultural heritage - Station 3 (NW view).

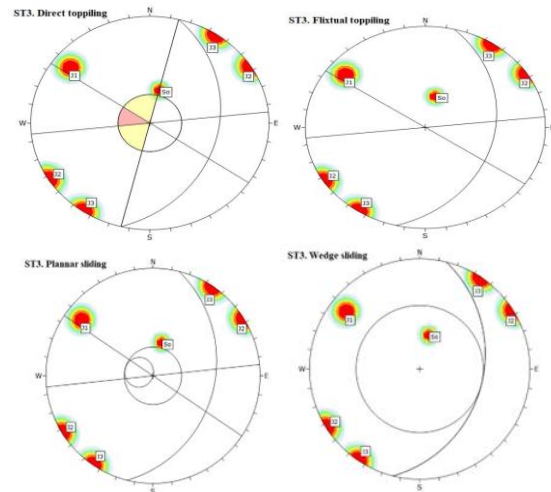


Fig. 13 Kinematic analysis of station 3.

The study area includes a natural heritage with a cultural heritage built on top of a ridge between two main roads. The main road runs from Erbil to Shaqlawa. The geological study reveals that the area had been exposed to various landslides due to the instability of hillside slopes. A common slope instability problem is the presence of hard rock lithotypes (such as limestones or sandstones) overlying a weak layer (such as clays or shales)

(Rodolfo et al., 2023). In the study area, the lithology of the beds ranges between hard sandstone rock underlying weak materials such as clay and siltstone of the Injana formation, in addition to the presence of fractures (joints) with the presence of water in the pore voids, leading to hazardous landslides. The study of the attitude and lithology of the beds, the occurrence of the collapses, and the types of collapses revealed that the study area is susceptible to potential collapses such as creep, toppling, wedge failure, and rockfall.

Assessment of Anthropogenic Impacts

The anthropogenic impacts on the cultural heritage area are studied by surveying the pathways around the castle and noticing that there are two pathways to the top of the hill to the castle gate, the first (the stairway) pathway. The second is that the new path is nearly parallel to the first, with a partially paved stairway on the top and not paved from the ground, wider than the old path, and allows vehicles to drive up the hill, which is not necessary and creates a large surface of erosion exposure (Fig. 14).

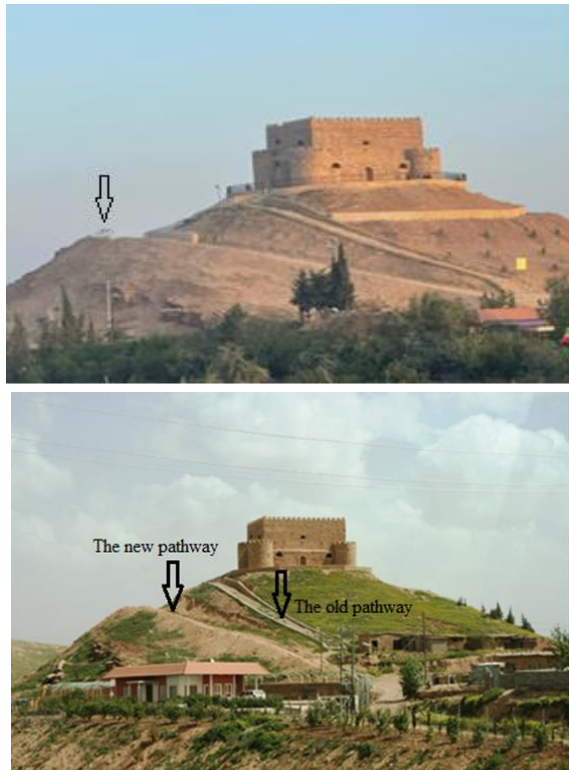


Fig. 14 Left- the new pathway is wide, showing the vehicle on top. Right- the two pathways are visible.

From the author's observation, the main road was to the west of the castle hill until the late nineties; a new road was constructed to the east of Khanzad-Banaman castle hill. Cultural heritage can play a role in

sustainable development. Various points highlight the role of cultural heritage (both tangible and intangible) in urban sustainable development. Moreover, some international organizations, such as UNESCO and ICOMOS (International Council on Monuments and Sites), highlight the key role of culture in achieving sustainable development (Nocca, 2017; Hosagrahar et al., 2016; Potts, 2016; Augustin, 2007). Transportation systems, such as highways, are vulnerable to rockfall wherever they cut across or skirt along mountains, plateaus, ridges and similar topographic features (Bunce et al., 1997; Hunger et al., 1999). Road construction has led to changes in the features of the surrounding lands along the road. The construction of the new road on the eastern side of Banaman-Khanzad castle has led to changes in the area and shape of the hill on which the castle is built (Fig.15). According to the researcher's observations, the area of the hill was larger and circular before the 1990s.



Fig. 15 Google image of the study area shows the two main roads on both sides of the cultural heritage hill.

The construction of the new road has affected the area and shape of the hill, as well as the stability of the hill and the castle. In addition to another human factor that negatively affected the stability of the hill by building a stair path from the bottom to the top of the hill to reach the castle, opening a new second stair path parallel to the old path led to the presence of new unstable slopes that led to more erosion and collapses of the type of clay rock creep, cracking and rockfall of sandstone and clay beds. Sufficiently maintaining the first old path and treating it was better than cutting a second unnecessary path, which increased the instability on the slopes (Fig. 16).

Humans are likely the premier geomorphic agent currently sculpting Earth's surface (Hooke, 1994). Earth is altered and the landscape modified, commonly degraded, by many of our activities (GAS

Today, 2012), (Szabó et al. 2010). Mining, infrastructure expansion, and urban development are obvious ones. Plowing moves huge amounts of earth and leads to accelerated erosion.



Fig. 16 The view shows a new wide road being cut, exposing the rocky slopes and the old stairway to gradual collapse.

As urban development and infrastructure expansion—particularly the construction of roads and tunnels—continue, environmental protection and nature conservation must be carefully considered, even when such structures are designed to harmonize with the natural landscape. The impacts of human-induced geomorphological processes in the area must also be evaluated. Slope cutting for the creation of new pathways has increased surface exposure to weathering and erosion, as observed at all the studied sites.

Threats to protected and other conservation areas can range from global threats relating to climate change, regional-scale threats such as habitat fragmentation, and localized problems including poaching, excessive visitor impacts and waste disposal. Developing and implementing response strategies to these threats is an essential part of protected area management (UNESCO, 2012). This study reveals that the study area is suffering from the threatening impacts of climatic, geological, and anthropogenic factors. To avoid damage to cultural heritage and the hazards of landslides, which can endanger the safety of tourists, the most effective factor is minimizing the pathways surrounding the cultural heritage by retaining the old pathway while closing the unnecessary new pathway.

Conclusion

The study area is characterized by its geological and geomorphological diversity, unique cultural heritage, and striking landscapes. However, it is also exposed to natural and anthropogenic factors that cause erosion and instability of the rocky slopes, triggering active

mass-wasting processes such as rockfalls, toppling, wedge failures, and creep. These processes pose a significant threat to the area's sustainability. Greater efforts should be made to preserve both the natural and cultural heritage, as they contribute substantially to the sustainable development of the region. Anthropogenic factors are altering the landscape's topography in both form and scale, leading to an expansion of eroded areas.

The designation of cultural heritage sites represents a commitment to safeguarding them for present and future generations. To preserve their values and integrity, authorities must uphold the highest standards of management and conservation, ensuring that these sites continue to serve as enduring symbols of history, identity, and collective memory. Climate risk management must also be integrated into heritage preservation strategies to ensure their long-term protection.

The author recommends that the original path should be properly maintained, as this is preferable to creating a second, unnecessary path, which has increased slope instability. As urban development and infrastructure expansion, particularly the construction of roads and tunnel continue, it is essential to carefully consider environmental protection and nature conservation, even when such structures are designed to blend with the natural landscape. Several methods can be employed to improve slope stability, including grouting to fill voids and strengthen rock surfaces, the use of materials such as steel mesh or fibre-reinforced polymers to reinforce the rock mass, and the construction of retaining walls to provide additional support.

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