Rockfall is a challenging risk factor in mountainous areas, with significant implications for safety and land management. Rockfall protection embankments (RPEs) play a crucial role in mitigating risks associated with multiple impacts or extremely high kinetic energies. Reinforced earth RPEs (RE-RPEs) are currently the most widely adopted solution compared to non-reinforced ones due to their smaller size and reduced earth material requirements. However, non-reinforced RPEs are still considered in emergency situations or specific contexts, such as mining operations.

This thesis aims to study the dynamic behavior of RPEs, both non-reinforced and reinforced, under impact conditions, addressing aspects currently unexplored in the literature. Both innovative experimental and numerical methods were employed.

For RE-RPEs, several analytical methods exist to predict the displacement field caused by impacts, which are usually compared with general recommendations. However, a clear scientific definition of RE-RPE failure—considering compaction, reinforcement performance, and soil-reinforcement interaction—is currently absent in the literature. To address this gap, three experimental campaigns were conducted to reproduce, on a reduced scale, the displacement field generated in RE-RPEs by impacting blocks up to their collapse configuration. From these experiments, a force-displacement curve was obtained, enabling the extraction of pre-collapse displacements. These tests were back-analyzed, demonstrating the capability to reproduce this curve numerically through a common FEM model.

Subsequently, starting from approaches described in the literature, numerical modeling improvements were developed using the Abaqus/Explicit code to simulate impacts on RPEs. These advancements enabled accurate simulation of foundation-embankment interaction, wrap-around reinforcement geometries, and parameter calibration for both compacted soil and reinforcement materials. A novel method for soil parameter calibration was proposed, based on data from Plate Load Tests frequently performed during RPE construction. This was complemented by geophysical tests conducted on three existing RE-RPEs, which proved to be a valid solution for acceptance testing. Additionally, innovative tensile tests were carried out on double-twist wire mesh, a common reinforcement material, to determine its elastic threshold and anisotropic behavior. The data were used to calibrate an elasto-plastic numerical model.

These numerical techniques supported an extensive parametric analysis on non-reinforced RPEs, involving over 2000 combinations, and a preliminary parametric analysis of RE-RPEs with 150 cases. Given the limited design methods currently available, the results for non-reinforced RPEs were elaborated into design tools that provide practical guidance under impact conditions without requiring numerical methods. For RE-RPEs, the analysis identified key parameters influencing their dynamic response.

Finally, the groundwork was laid for innovative full-scale tests designed to investigate unprecedented energy levels in a controlled testing environment, enabling robust calibration of numerical models. A detailed experimental setup was designed, including a network of 32 sensors embedded in the embankment, 6 sensors in the impacting block, and a photogrammetric system to capture dynamic 3D deformations during testing.