Rock Engineering

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Module 1: The Development of Rock Engineering

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the historical catalysts and catastrophic failures that transformed rock engineering into a formal technical discipline.
- **Evaluate** the transition from pure elastic theory to the integrated discontinuum approach in modern rock mass analysis.
- **Select** appropriate investigative tools for geological data collection, in situ stress measurement, and rock mass classification.

Executive Summary: Modern rock engineering has evolved from a reliance on theoretical elastic models to a practical, integrated discipline that accounts for the discontinuous, inhomogeneous nature of rock masses. This shift was driven by significant engineering failures in the 1960s and has been accelerated by advanced numerical modeling and standardized classification systems like RMR, Q, and GSI.

Introduction

While fundamental principles date back to the 18th century (Coulomb, 1773), the discipline emerged as a formal field in the early 1960s following several catastrophic failures. These events proved that engineers were "overstepping the limits" of their predictive capabilities.

Key Historical Failures

- **Malpasset Dam (1959):** Foundation failure of a concrete arch dam; 450 fatalities.
- **Vajont Dam (1963):** Landslide-generated wave overtopped the dam; 2,500 fatalities.
- **Coalbrook Mine (1960):** Massive pillar collapse; led to standardized coal pillar design methods.

Figure 1: Remains of the Malpasset Dam as seen today. Photograph by Mark Diederichs, 2003.

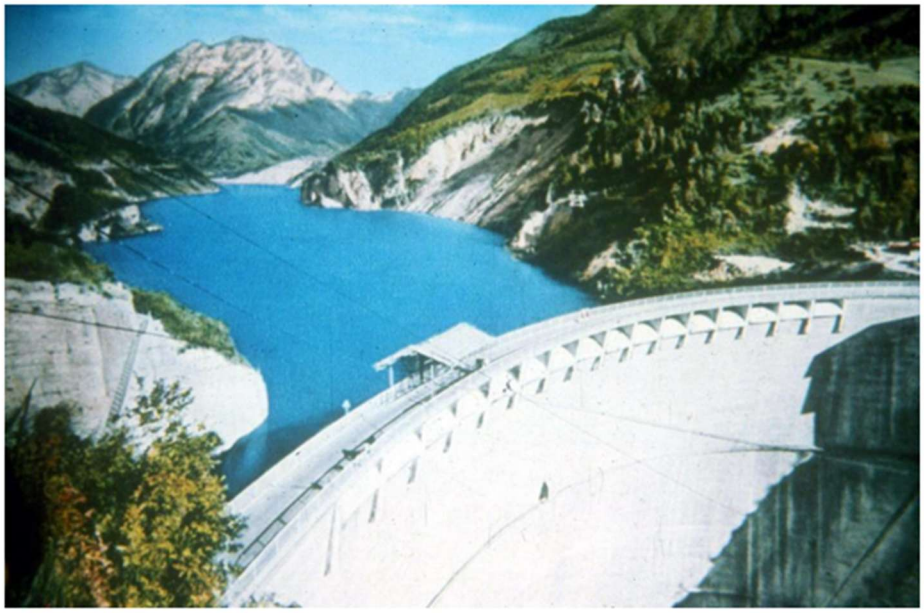

Figure 2a: The Vajont dam during impounding of the reservoir. In the middle distance, in the centre of the picture, is Mount Toc with the unstable slope visible as a white scar on the mountain side above the waterline.

Figure 2b: During the filling of the Vajont reservoir the toe of the slope on Mount Toc was submerged and this precipitated a slide. The mound of debris from the slide is visible in the central part of the photograph. The very rapid descent of the slide material displaced the water in the reservoir causing a 100 m high wave to overtop the dam wall. The dam itself, visible in the foreground, was largely undamaged.

Figure 2c: The town of Longarone, located downstream of the Vajont dam, before the Mount Toc failure in October 1963.

Figure 2d: The remains of the town of Longarone after the flood caused by the overtopping of the Vajont dam as a result of the Mount Toc failure. More than 2000 persons were killed in this flood.

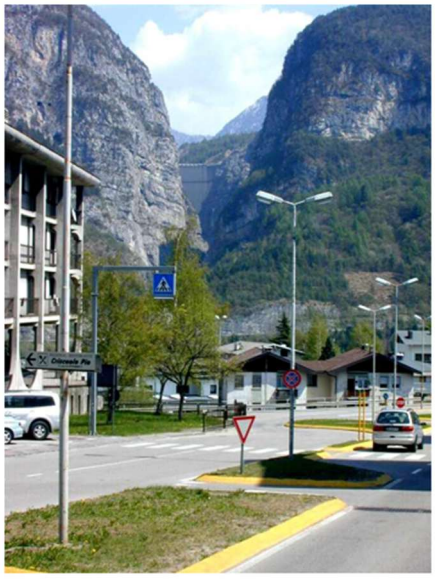

Figure 2e: The remains of the Vajont dam perched above the present town of Longarone. Photograph by Mark Diederichs, 2003.

Rockbursts and Elastic Theory

Historically, rock mechanics development was split between distinct schools of thought. The study of **rockbursts**—explosive failures in high-stress, brittle environments—dominated the English-speaking world.

- **Approach:** Heavily focused on the **Theory of Elasticity**.
- **Constraint:** Assumed isotropic elastic rock and largely ignored structural discontinuities.
- **Benefit:** Provided the foundation for modern underground excavation design and microseismic monitoring.

Figure 3: The results of a rockburst in an underground mine in brittle rock subjected to very high stresses.

Discontinuous Rock Masses

Pioneered by Josef Stini, the European approach emphasized the role of **structural discontinuities** (joints, faults, bedding planes).

- **Focus:** Near-surface civil engineering works where structure, rather than intact rock strength, controls behavior.
- **Evolution:** The Malpasset and Vajont disasters catalyzed three-dimensional structural analyses.

Figure 4: A wedge failure controlled by intersecting structural features in the rock mass forming the bench of an open pit mine.

Modern Rock Engineering Integration

Current practice represents a "mature" discipline that merges elastic theory with the discontinuum approach. Engineers now recognize that rock acts as both an elastic material and a discontinuous mass, while incorporating soil mechanics for soft rocks and rheological models for materials like salt.

Purchase this course to see the remainder of the technical materials.