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Maestría en Ingeniería Geotécnica - MIG
(Carrera Binacional Argentina - Alemania)

Asignatura ACMIG04:

Mecánica de Rocas

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Modelado en Mecánica de Rocas

ACMIG04: Mecánica de Rocas

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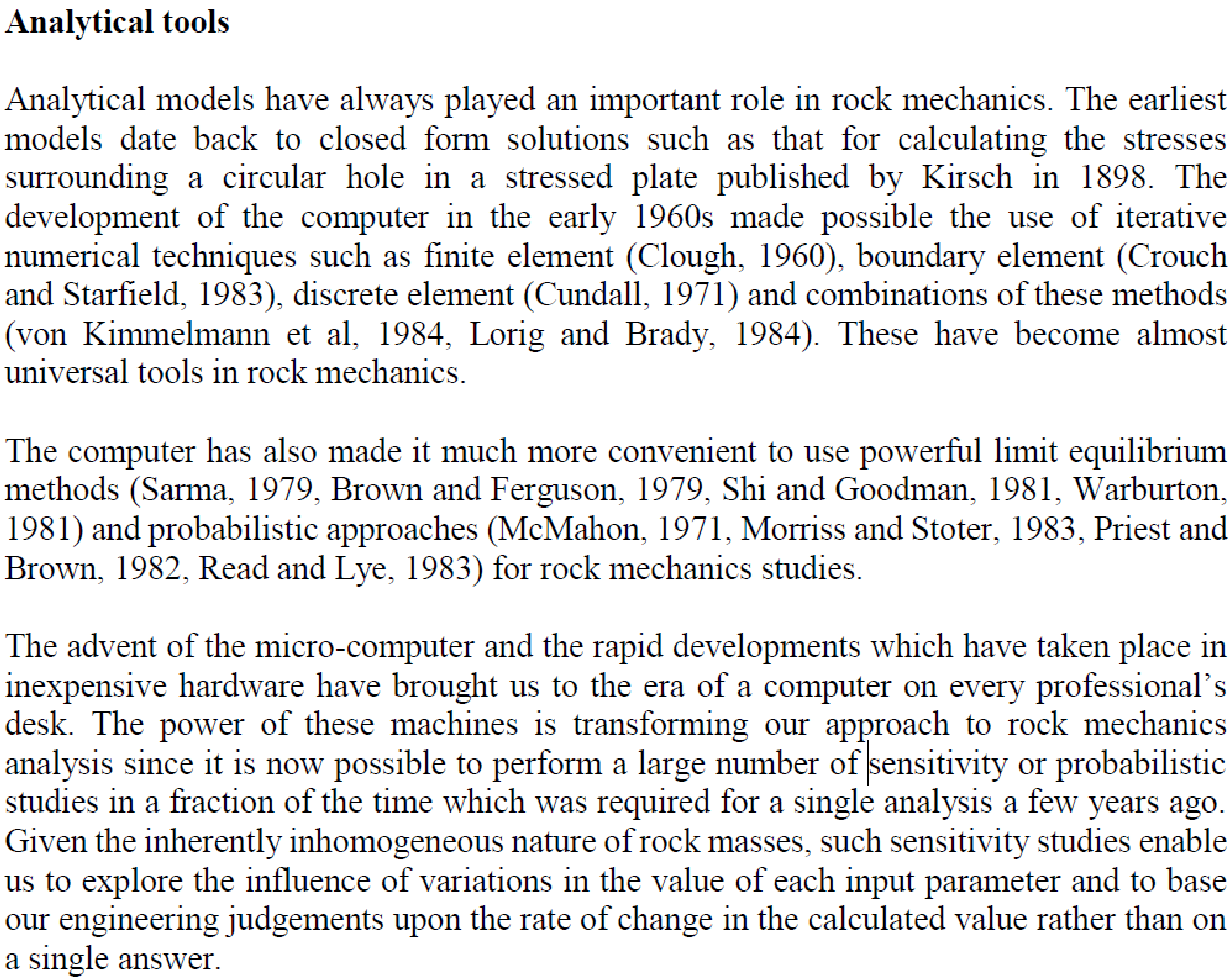
Modelado en Mecánica de Rocas

Temas:

- Conceptos de Hoek
- El modelado en la Ingeniería de rocas
- Modelos continuos
- Modelos discretos

Conceptos de Hoek



Analytical tools

Analytical models have always played an important role in rock mechanics. The earliest models date back to closed form solutions such as that for calculating the stresses surrounding a circular hole in a stressed plate published by Kirsch in 1898. The development of the computer in the early 1960s made possible the use of iterative numerical techniques such as finite element (Clough, 1960), boundary element (Crouch and Starfield, 1983), discrete element (Cundall, 1971) and combinations of these methods (von Kimmelmann et al, 1984, Lorig and Brady, 1984). These have become almost universal tools in rock mechanics.

The computer has also made it much more convenient to use powerful limit equilibrium methods (Sarma, 1979, Brown and Ferguson, 1979, Shi and Goodman, 1981, Warburton, 1981) and probabilistic approaches (McMahon, 1971, Morriss and Stoter, 1983, Priest and Brown, 1982, Read and Lye, 1983) for rock mechanics studies.

The advent of the micro-computer and the rapid developments which have taken place in inexpensive hardware have brought us to the era of a computer on every professional's desk. The power of these machines is transforming our approach to rock mechanics analysis since it is now possible to perform a large number of sensitivity or probabilistic studies in a fraction of the time which was required for a single analysis a few years ago. Given the inherently inhomogeneous nature of rock masses, such sensitivity studies enable us to explore the influence of variations in the value of each input parameter and to base our engineering judgements upon the rate of change in the calculated value rather than on a single answer.

El caso Vajont:

las ciencias avanzan a partir de eventos icónicos.

the resulting flood killed about 450 people (Figure 1). In October 1963 about 2500 people in the Italian town of Longarone were killed as a result of a landslide generated wave which overtopped the Vajont dam (Figure 2). These two disasters had a major impact on rock mechanics in civil engineering and a large number of papers were written on the possible causes of the failures (Jaeger, 1972).

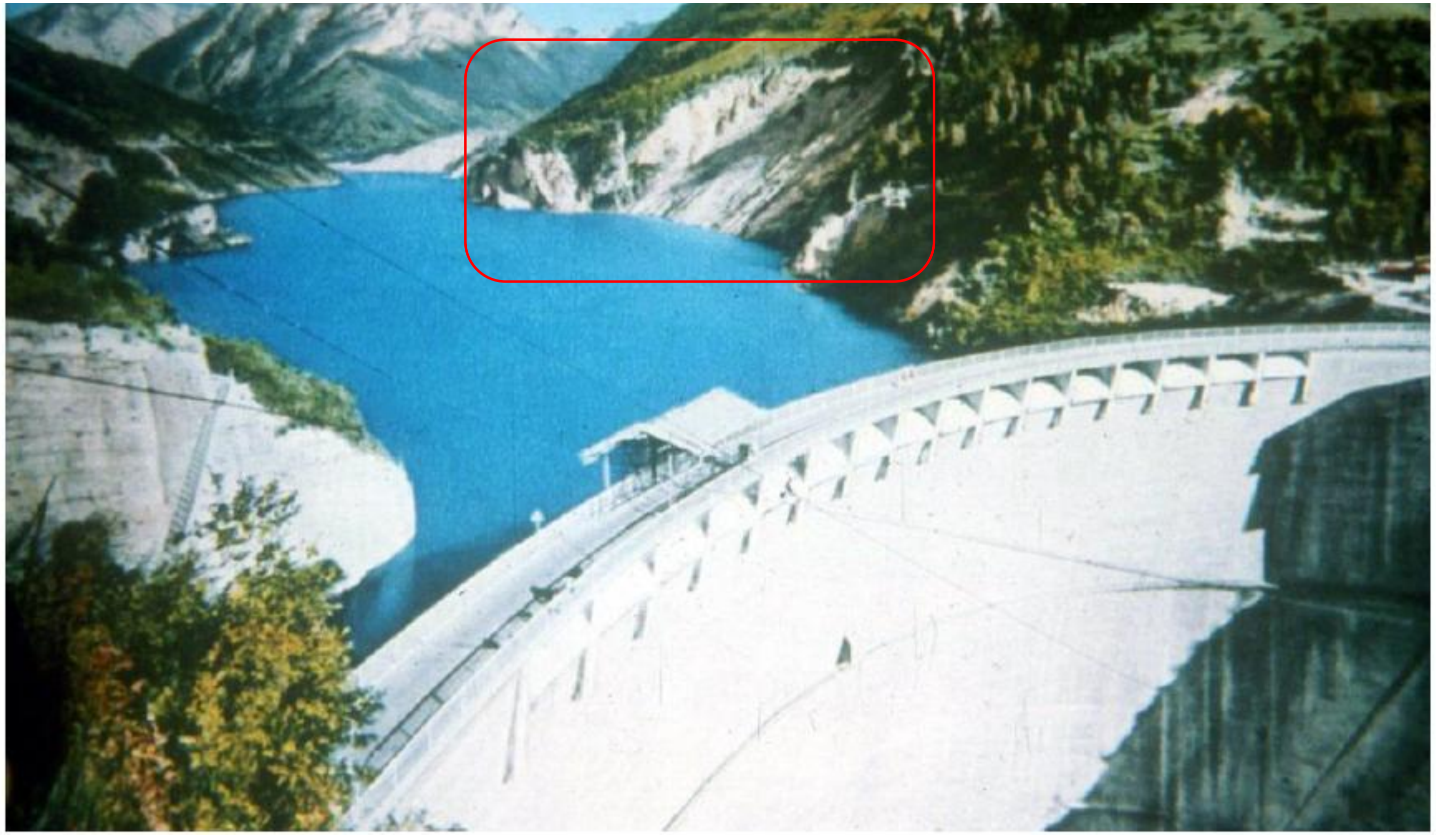


Figure 2a: The Vajont dam during impounding of the reservoir. In the middle distance, in the centre of the picture, is Mount Toc with the unstable slope visible as a white scar on the mountain side above the waterline.

El caso Vajont:

De la realidad en campo al modelado numérico: UN LARGO CAMINO

De la realidad en campo al modelado numérico: 4 pasos necesarios.

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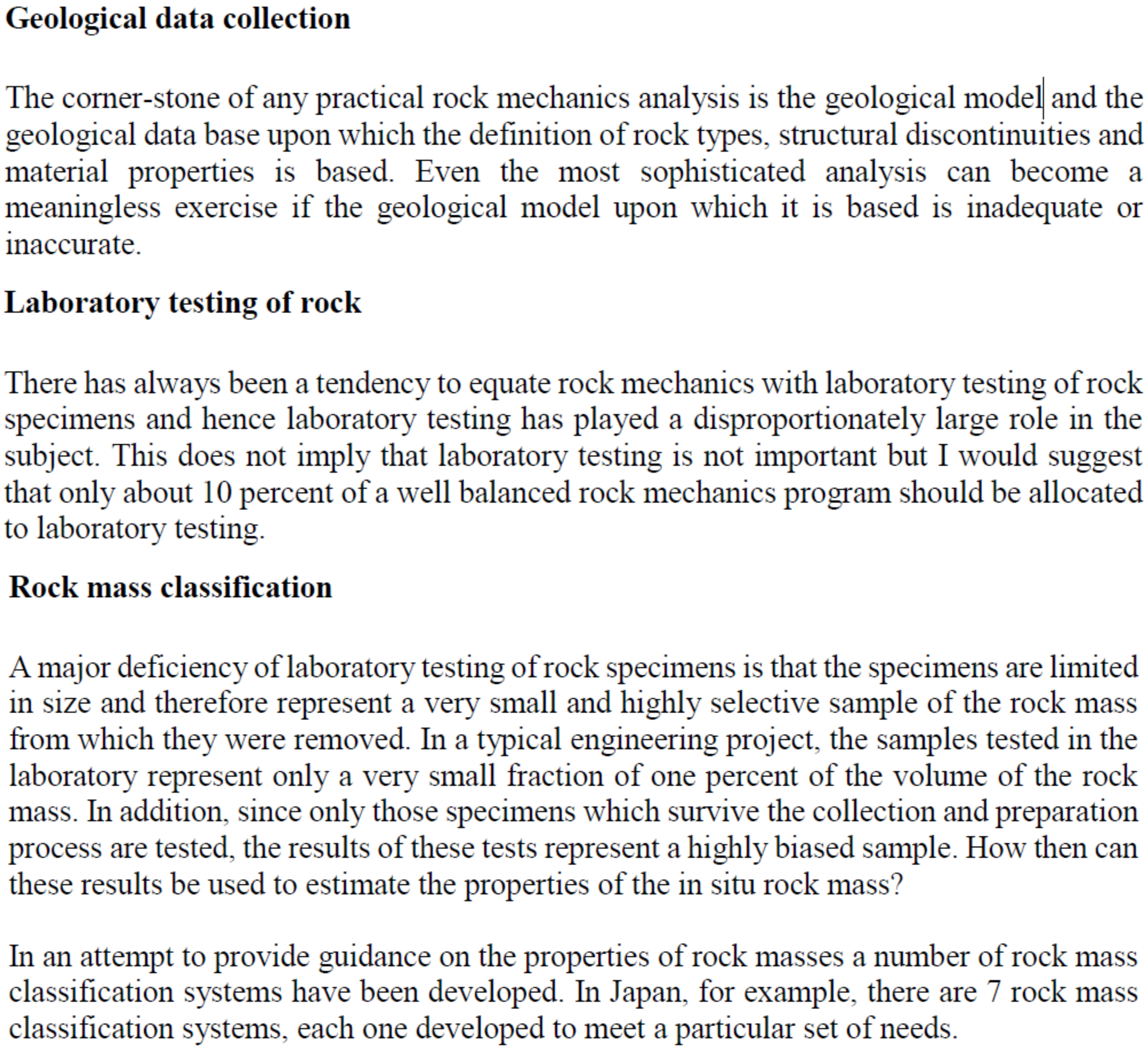
?

?

?

Conceptos de Hoek



Geological data collection

The corner-stone of any practical rock mechanics analysis is the geological model and the geological data base upon which the definition of rock types, structural discontinuities and material properties is based. Even the most sophisticated analysis can become a meaningless exercise if the geological model upon which it is based is inadequate or inaccurate.

Laboratory testing of rock

There has always been a tendency to equate rock mechanics with laboratory testing of rock specimens and hence laboratory testing has played a disproportionately large role in the subject. This does not imply that laboratory testing is not important but I would suggest that only about 10 percent of a well balanced rock mechanics program should be allocated to laboratory testing.

Rock mass classification

A major deficiency of laboratory testing of rock specimens is that the specimens are limited in size and therefore represent a very small and highly selective sample of the rock mass from which they were removed. In a typical engineering project, the samples tested in the laboratory represent only a very small fraction of one percent of the volume of the rock mass. In addition, since only those specimens which survive the collection and preparation process are tested, the results of these tests represent a highly biased sample. How then can these results be used to estimate the properties of the in situ rock mass?

In an attempt to provide guidance on the properties of rock masses a number of rock mass classification systems have been developed. In Japan, for example, there are 7 rock mass classification systems, each one developed to meet a particular set of needs.

Conceptos de Hoek

Rock mass strength

One of the major problems confronting designers of engineering structures in rock is that of estimating the strength of the rock mass. This rock mass is usually made up of an interlocking matrix of discrete blocks. These blocks may have been weathered or altered to varying degrees and the contact surfaces between the blocks may vary from clean and fresh to clay covered and slickensided.

In situ stress measurements

The stability of deep underground excavations depends upon the strength of the rock mass surrounding the excavations and upon the stresses induced in this rock. These induced stresses are a function of the shape of the excavations and the in situ stresses which existed before the creation of the excavations. The magnitudes of pre-existing in situ stresses have been found to vary widely, depending upon the geological history of the rock mass in which they are measured (Hoek and Brown, 1980). Theoretical predictions of these stresses are considered to be unreliable and, hence, measurement of the actual in situ stresses is necessary for major underground excavation design. A phenomenon which is frequently observed in massive rock subjected to high in situ stresses is ‘core disking’, illustrated in Figure 10.

Modelado en Mecánica de Rocas

Conceptos de Hoek

Groundwater problems

The presence of large volumes of groundwater is an operational problem in tunnelling but water pressures are generally not too serious a problem in underground excavation engineering. Exceptions are pressure tunnels associated with hydroelectric projects. In these cases, inadequate confining stresses due to insufficient depth of burial of the tunnel can cause serious problems in the tunnel and in the adjacent slopes. The steel linings for these tunnels can cost several thousand dollars per metre and are frequently a critical factor in the design of a hydroelectric project. The installation of a steel tunnel lining is illustrated in Figure 13.

Rock reinforcement and support design

Safety during construction and long term stability are factors that have to be considered by the designers of excavations in rock. It is not unusual for these requirements to lead to a need for the installation of some form of rock reinforcement or support. Fortunately, practical developments in this field have been significant during the past 25 years and today's rock engineer has a wide choice of reinforcement systems and tunnel lining techniques. In particular, the development of shotcrete has made a major contribution to modern underground construction.

Excavation methods in rock

As pointed out earlier, the strength of jointed rock masses is very dependent upon the interlocking between individual rock pieces. This interlocking is easily destroyed and careless blasting during excavation is one of the most common causes of underground excavation instability. The following quotation is taken from a paper by Holmberg and Persson (1980):

Modelado en Mecánica de Rocas

Conceptos de Hoek

Refuerzo vs. Soporte

There has been considerable confusion in the use of the terms "reinforcement" and "support" in rock engineering and it is important for the reader to understand the different roles of these two important systems.

Rock reinforcement, as the name implies, is used to improve the strength and/or deformational behaviour of a rock mass in much the same way that steel bars are used to improve the performance of reinforced concrete. The reinforcement generally consists of bolts or cables that are placed in the rock mass in such a way that they provide confinement or restraint to counteract loosening and movement of the rock blocks. They may or may not be tensioned, depending upon the sequence of installation, and they may or may not be grouted, depending upon whether they are temporary or permanent. In general, rock reinforcement is only fully effective in reasonably frictional rock masses of moderate to high strength. Such rock masses permit effective anchoring of the reinforcement and they also develop the interlocking required to benefit from the confinement provided by the reinforcement. In reinforced rock masses, mesh and/or shotcrete play an important role in bridging the gap between adjacent bolt or anchor heads and in preventing progressive ravelling of small pieces of rock that are not confined by the reinforcement.

For weak to very weak rock masses that are more cohesive than frictional, reinforcement is less effective and, in the case of extremely weak materials, may not work at all. In these cases it is more appropriate to use support rather than reinforcement. This support, which generally consists of steel sets and shotcrete or concrete linings in different combinations, must act as a load bearing structural shell to be fully effective in failing weak ground. The

Cuadrantes del modelado:

Dominio espacial

(Modelo geológico – Estudios de Campo)

(Límites significativos)

(Excavaciones, cortes)

Condicionantes del Dominio

(Condiciones iniciales y de contorno)

(Solicitaciones – Agua – Etapas)

(refuerzos, sostenimientos)

Mecánica del Dominio

(Laboratorio – Clasificación geomecánica)

(Modelos constitutivos)

(Parámetros de los Materiales)

Modelo del Dominio

(Discretización – Cálculo – Acoplamientos)

(Etapas – Resultados)

(Análisis de sensibilidad)

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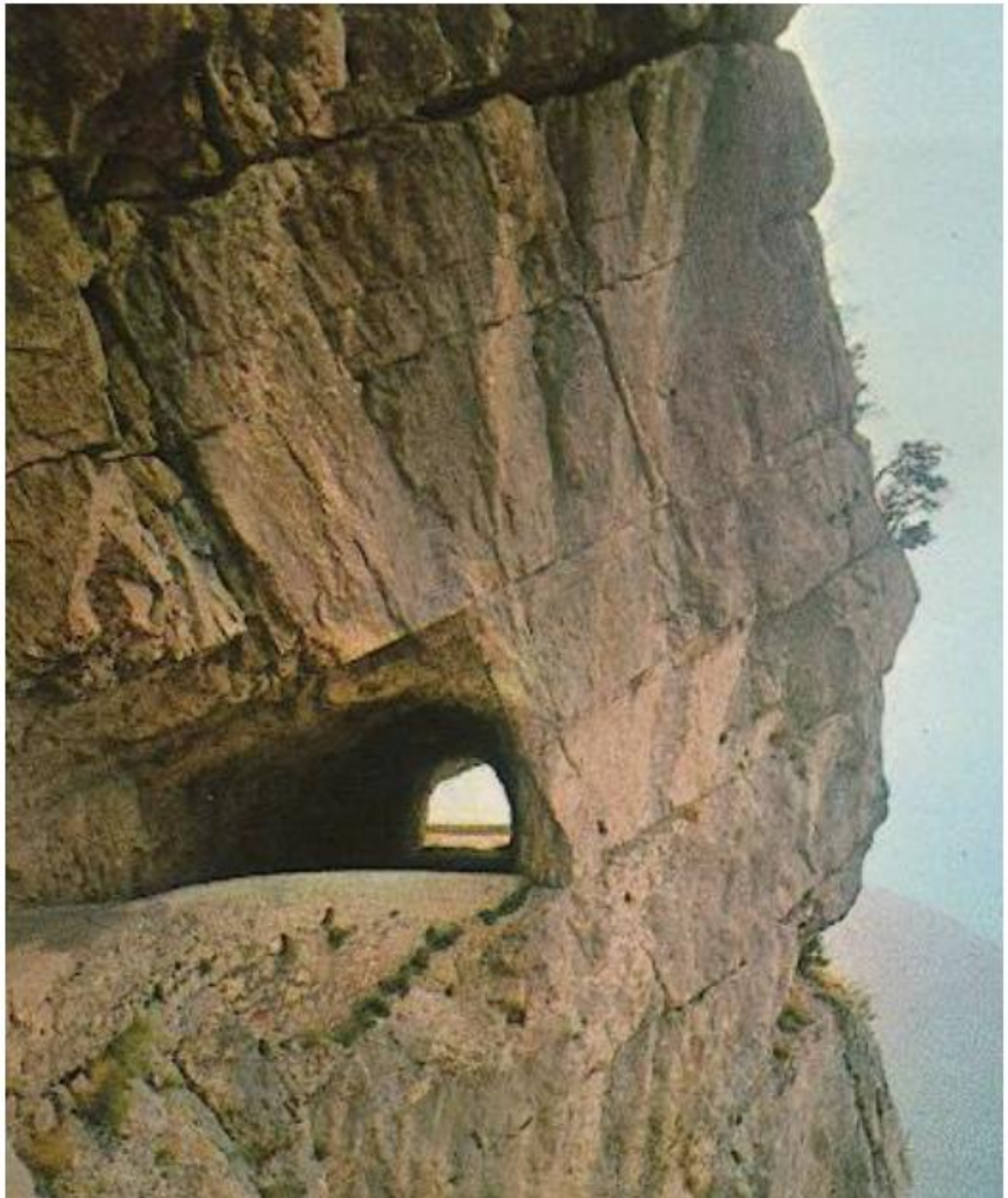

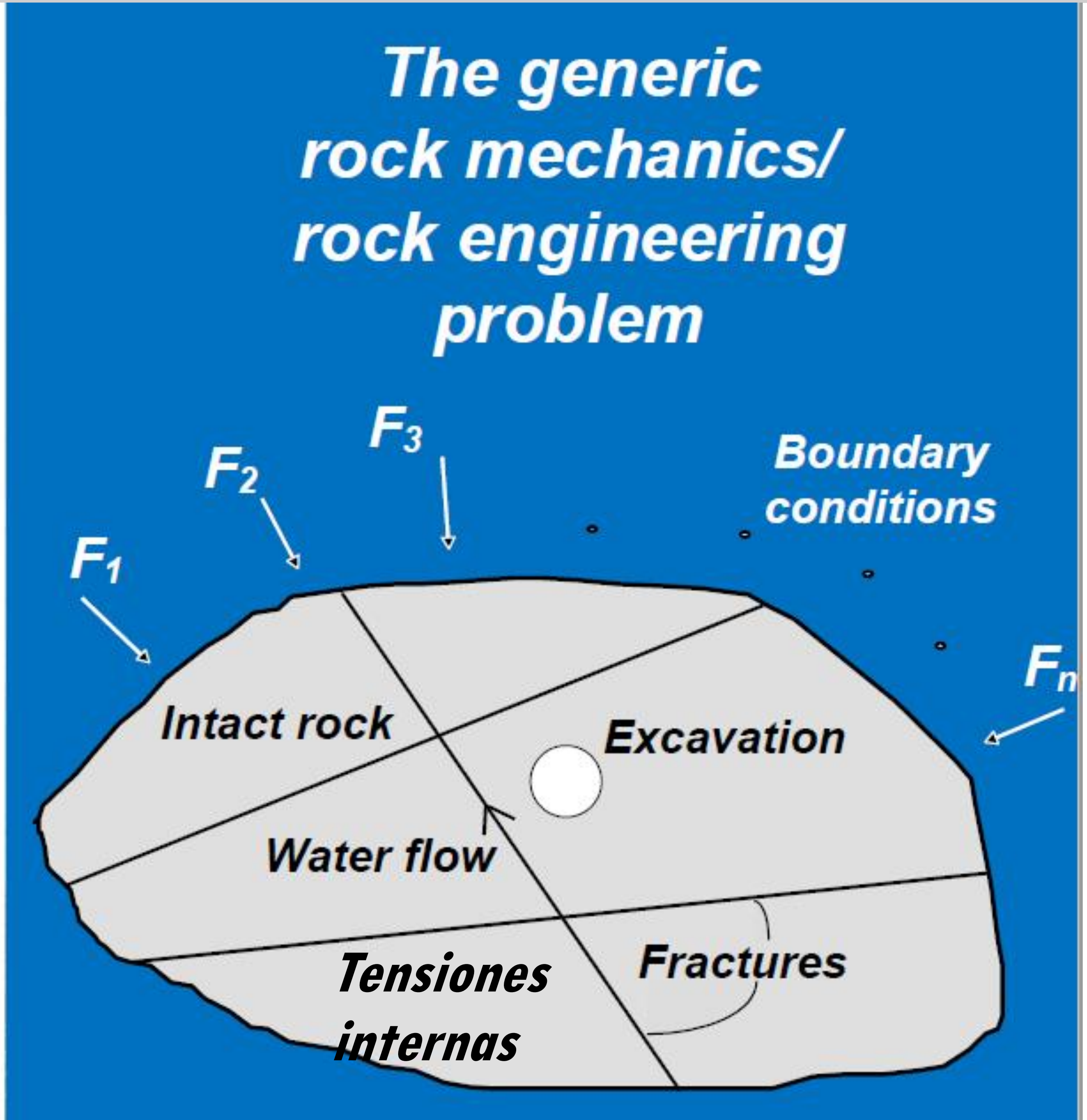

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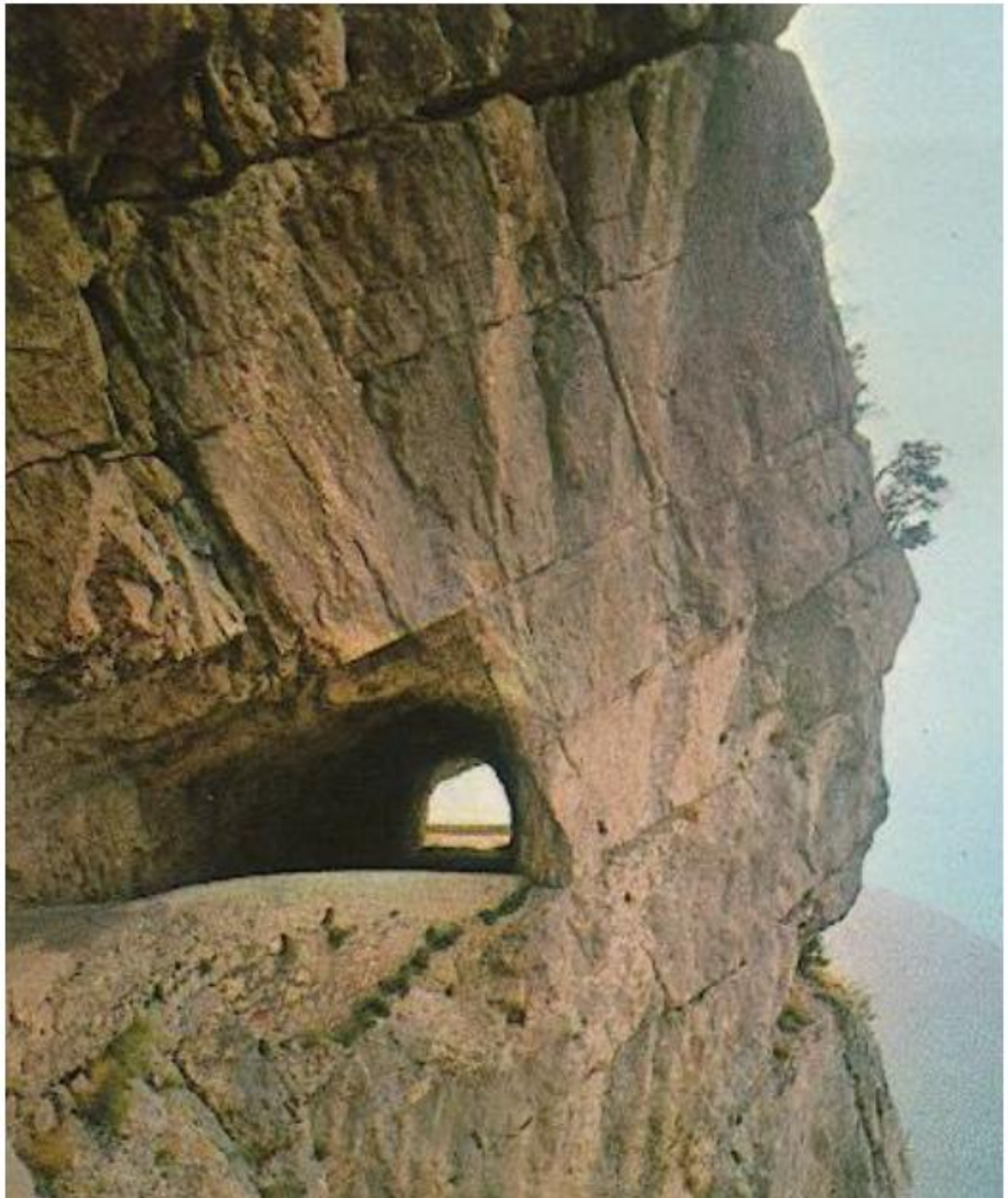

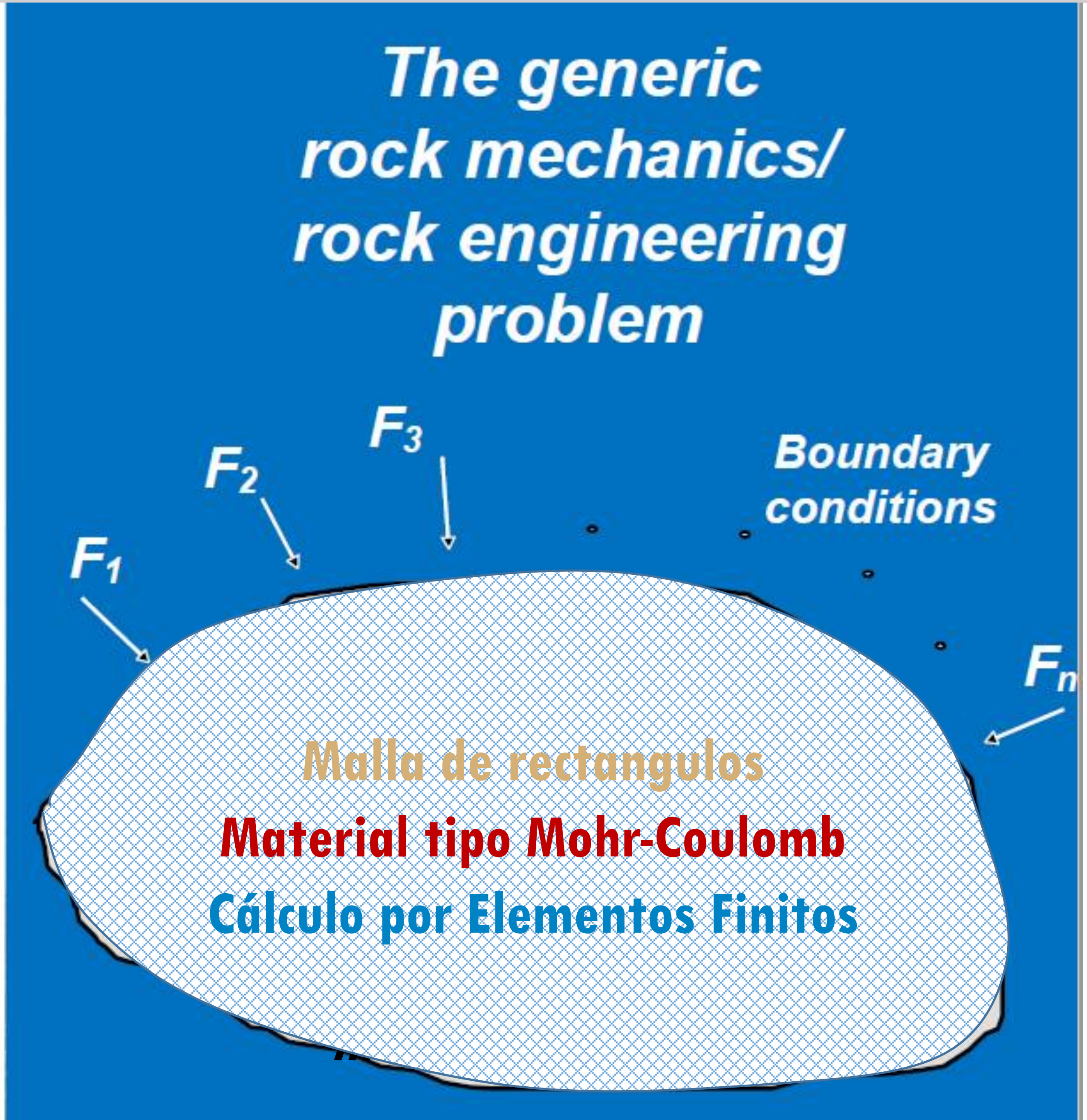

The generic rock mechanics/ rock engineering problem

Malla de rectangulos

Material tipo Mohr-Coulomb

Cálculo por Elementos Finitos

Modelado numérico según la escala:

- La escala de la **Matriz Rocosa**:
  - Modelar el fragmento de roca: Ej. ensayos de laboratorio y Roca Digital.
  - Escala de los minerales.
- La escala del **Macizo Rocoso**:
  - Modelar obras: taludes, túneles, excavaciones, etc.
  - Escala de las discontinuidades.
- La escala de la **Unidad Geomorfológica**:
  - Modelar regiones: Ej. Yacimientos y explotaciones mineras.
  - Escala de las formaciones, estructuras y fallas.

Modelado numérico según sus paradigmas:

- Mecánica del Continuo:
  - Bajas deformaciones: Elementos finitos, Diferencias finitas.
  - Grandes deformaciones: Método del Punto Material.
- Mecánica Discreta:
  - Sistemas de bloques: DDA, UDEC, etc.

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