Chapter 1

Introduction

The life of a civil structure depends on the physical and engineering properties of its foundation material. As we know that the earth's surface is made up of different types of rock and soil with different physical and mechanical properties, which depend on the local geological surface and subsurface strata, geological features, hydrology, geomorphology and biological activities of that area.

Engineering geology is the application of geology which is used in design, construction and performance of civil engineering projects and development activities as well as geological hazard mitigation measures.

Engineering geological studies performed during the planning, environmental impact analysis, civil or structural engineering design, value engineering and construction phases of public and private works/projects and during post-construction and forensic phases of projects. Figure 1.1 shows the dominating factors of engineering geology and the outcomes.

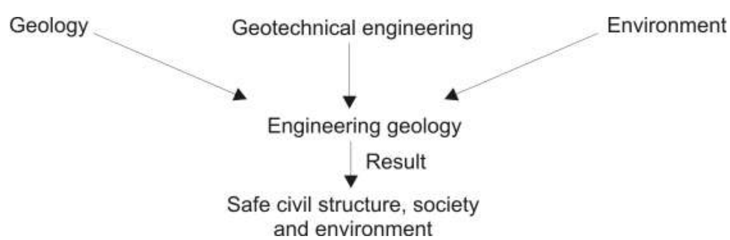

Fig. 1.1: Basic factors and result of engineering geology

1.1 HISTORY OF ENGINEERING GEOLOGY

Failure of civil structure and/or foundation is not new in human civilization. One of the world's best foundation failure examples is the Tower of Pisa. The tower of Pisa was tilted at an angle of 5.5° and after the applied stabilization technique and it is 3.97° tilt.

The first book *Engineering Geology* was published in England in year 1880 by William Penning and first American engineering geology textbook was written in 1914 by Ries and Watson. In 1921, Reginald W Brock, the first Dean of Applied Sciences, University of British Columbia, started the first undergraduate and graduate degree programs in geological engineering. In 1925, Karl Terzaghi, an Austrian trained engineer and geologist, published the first text in *Soil Mechanics* (in German). Terzaghi is known as the parent of soil mechanics, but also had a great interest in geology; Terzaghi considered soil mechanics to be a sub-discipline of engineering geology. In 1929, Terzaghi, along with Redlich and Kampe, published their own engineering geology text.

The need for geologist on engineering works gained worldwide attention in year 1928 with the failure of the St Francis dam in California and the loss of 426 lives. More engineering failures which were occurred through the following years also prompted the requirement for engineering geologists to work on large engineering projects.

Geomorphological studies, structural geology, stratigraphy, petrology and four dimensional visualization (length, width, height and time-dimensions) as well as changes in engineering properties of material according to time; is the base of better understanding of engineering geology by geologists.

Reason behind the tilting of Tower of Pisa and the causes of failure of the St Francis dam are discussing below for better understanding and the need of engineering geology.

1.1.1 Study of causes for tilting of Tower of Pisa

The Tower of Pisa is a tilted tower, situated in the Italian city of Pisa. The height of the tower is 55.86 meters from the ground on the low side and 56.67 meters on the high side. The construction of the tower occurred in three phases, spanning nearly two centuries, delay due to social and political reasons. Work on the ground floor of the white marble campanile began on August 14, 1173. The tower began to sink after construction had progressed to the second floor in 1178. This was due to a mere three-meter foundation, set in a weak, unstable subsoil, a design that was flawed from the beginning. Construction was subsequently halted for almost a century for political reason that allowed time for the underlying soil to settle. In 1272, construction resumed, in an effort to compensate for the tilt, the engineers built upper floors with one side taller than the other. Construction of tower was completed in 1372.

It was known prior to the start of this stabilization effort that the tower had been built atop an inadequate foundation, on very soft silty soil. But it was not sufficient to explain about tilting of tower. An English geotechnical engineer, John Burlandhas spent the last two decades (1990–2010) striving to save and understand the leaning Tower of Pisa, given primary causes of the tilting of tower; who discovered that there was a fluctuating water table which would perch higher on the tower’s north side, causing the tower’s characteristic slant to the south (www.Madridengineering.com).

It means, the fluctuating water table has been changed the foundation load bearing capacity and Tower of Pisa has been tilted. Stages of tilting of Tower of Pisa and subsoil strata have been given in Figs 1.2 and 1.3.

1.1.2 Study of St Francis dam failure

The St Francis dam was a curved concrete gravity dam, built in year 1924–1926 to create a large regulating and storage reservoir for the City of Los Angeles, California. It was located in San Francisquito canyon of the Sierra Pelona mountains, about 40 miles (64 km) northwest of downtown Los Angeles. The collapse of the St Francis dam is considered to be one of the worst American civil engineering disasters of the 20th century and remains the second-greatest loss of life in California’s history, after the 1906 San Francisco earthquake and fire.

The mid and upper portion of the western hillside of dam site area consisted mainly of a reddish colored conglomerate and sandstone formation that had small strings

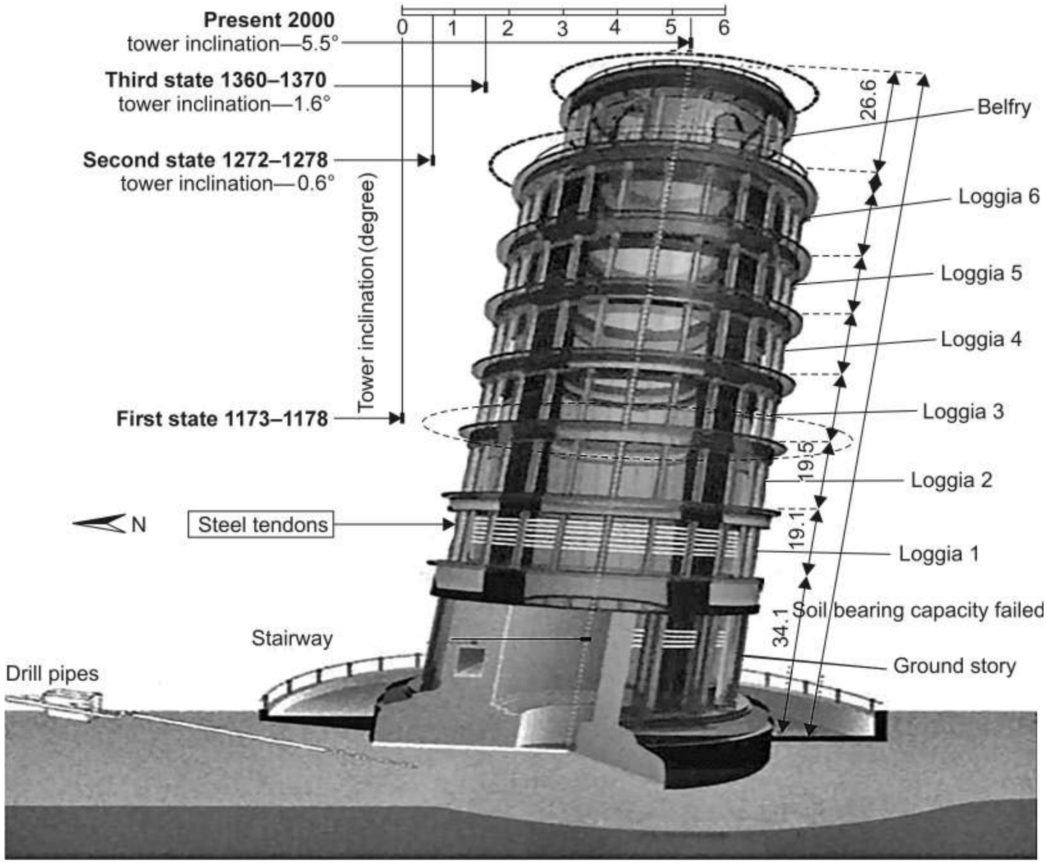

Fig. 1.2: Stages of tilting of Tower of Pisa

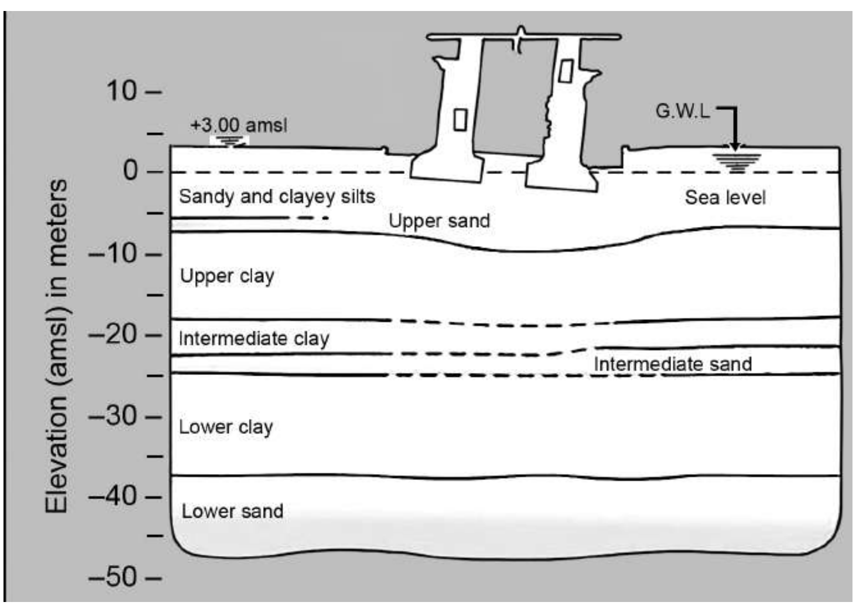

Fig. 1.3: Subsurface profile of Tower of Pisa (www. madridengineering.com)

of gypsum interspersed within it. Below the red conglomerate, down the remaining portion of the western hillside, crossing the canyon floor and up the eastern wall, a drastically different rock composition prevailed. These areas were made up of mica schist that was severely laminated, cross-faulted in many areas and interspersed with talc. Although, later many geologists opinion placed that dam on the inactive San Francisquito fault line.

After completion of the dam, water began to fill in the reservoir on March 12, 1926. It rose steadily and rather uneventfully, although several cracks did appear in the dam and a minor amount of seepage began to flow from the abutments. On March 12, 1928, at 11:57 pm; the dam catastrophically failed, and the resulting flood took the lives of as many as 426 people.

The collapse of the dam prompted the creation of an investigation into the cause of failure. According to report, geological factor was behind it. They reveal that, in areas, the wall was 2 to 6 inches higher than when built. Geological cross-section of dam is shown in Fig. 1.4, inactive San Francisquito fault line was present in west abutment, as water seepage started along this fault plane and along foliation of mica schist in east abutment; schist changed its physical property and worked as lubricated. In the west abutment of dam, red conglomerate swelled and expended. Therefore, the dam was caught between forces that were acting on it much like a vise, as the red conglomerate swelled on one side, and the moving mountain pressed in on it from the other and this incident happened.

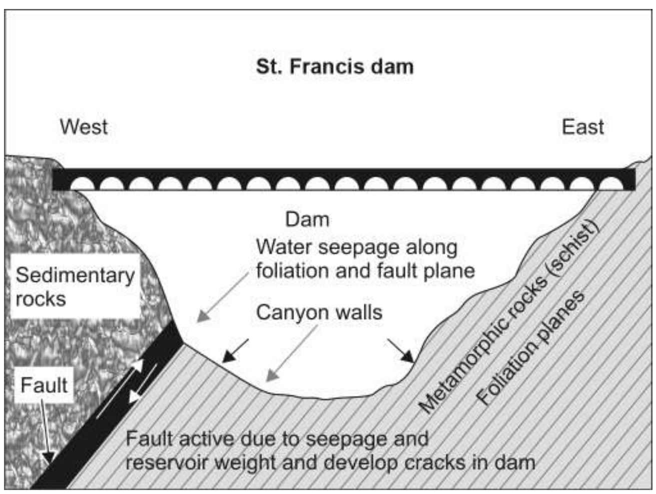

Fig. 1.4: Geological cross-section and causes of failure of St Francis dam (After Sarah Gray, 2007)

1.2 IMPORTANCE OF ENGINEERING GEOLOGY IN DEVELOPMENT

- To recognise potential difficult ground conditions prior to detailed design and construction
- It helps to identify areas susceptible to failure due to geological hazards
- To establish civil design specifications
- To have the best selection of site for engineering projects
- To have the best selection of engineering materials in view of quality and project

1.3 AREA COVERED BY ENGINEERING GEOLOGY

- The most important role of the engineering geology is the interpretation of landforms and earth processes to identify potential geologic and related man-made hazards that may impact civil structures and human development.
- Civil engineering projects and geotechnical projects (investigation and construction of roads, bridges, power plants, dams, reservoirs, tunnel, large building structure, underground structures, mining, etc.)
- Geological hazard mitigation measures
- Material properties
- Landslide and slope stability
- Seismic studies.

1.4 BASIC STUDY REQUIRED BY ENGINEERING GEOLOGISTS

- Geological field mapping which includes geological structures, formations, soil/rock units and probable hazards
- Review of geological literatures, maps, geotechnical reports, engineering plans, environmental reports, arial photographic studies, remote sensing data, topographical map, etc.
- The surface and subsurface investigations for engineering property of foundation or constructed medium (soil/rock), geotechnical and geo-mechanical test, geophysical survey, hydrological tests, etc. as per design requirement
- Deformation monitoring of soil/rock on surface and subsurface
- Recommendation for safety measures and design parameters

QUESTIONS

1. Define engineering geology.
2. Discuss the role of engineering geology in civil engineering projects.
3. Explain the origin and importance of engineering geology studies.
4. Explain the role of engineering geology in the tilting of the Tower of Pisa and the failure of the St. Francis dam.

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