Geotechnical Engineering

R.K. Khitoliya
Pardeep Kumar Gupta

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R. K. Khitoliya
Pardeep Kumar Gupta
Civil Engineering Department
PEC University of Technology
Chandigarh

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In the Memory of our Mothers

Preface

A sound knowledge of the fundamental principles of soil mechanics is essential to predict the behaviour and performance of soil as a construction material or as a foundation. Every site has different problems and sometimes the geotechnical engineer meets with surprises.

The material presented in this book has been designed to suit graduate course. Each chapter has been separately introduced with due emphasis on the practical aspects of the subject matter. A comprehensive range of illustrative examples are given at the end of each chapter followed by practice exercises.

The material has been drawn freely from various books, technical publications, etc., which provided source material for this book and we express our sincere thanks to them. In spite of sincere efforts, some contributions might not have been acknowledged, such omissions are not intentional and we regret for the same.

We will greatly appreciate for being informed about errors and constructive criticism for improving the book.

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Contents

CHAPTER 1

Introduction

1.1 IMPORTANCE OF SOIL ENGINEERING

Once it is accepted that soil is a structural material, its importance in Civil Engineering becomes paramount. A Geotechnical Engineer should have thorough knowledge of this material of structure as in the case of any other structural material.

Study of Soil Engineering is particularly important in respect of infrastructure development and constructions, viz., highway and airport pavements, foundations and underground structures, retaining walls and embankments and multistorey buildings.

Foundation is considered the most critical part of any structure and it is on its soundness that the stability of the entire structure depends. Since the load bearing capacity of the foundation has a direct relationship with the soil characteristics, the importance of soil investigation should not be underestimated.

1.2 FUNDAMENTALS

The word 'soil' derives from the Latin word **solium**, which means, the upper layer of the earth that may be dug or powdered, specifically, the loose surface material of the earth in which plants grow.

The term 'soil' in soil engineering is defined as an unconsolidated material composed of solid particles, produced by the disintegration of rocks. The void space between the particles may contain air, water or both. The solid particles may contain organic matter. The soil particles can be separated by such mechanical means as agitation in water.

A natural aggregate of mineral particles bonded by strong and permanent cohesive forces is called a 'rock'.

Application of laws and principles of mechanics and hydraulics to engineering problems in dealing with soil is usually referred to as Soil Mechanics. The term soil engineering is used to cover a much wider scope implying that it is a practical science rather than a purely fundamental or mathematical one. Hence, Soil Engineering is an applied science dealing with the application of the principles of soil mechanics to practical problems.

It includes site investigation, design and construction of the foundation, earth retaining structures and earth structures.

1.3 HISTORICAL REVIEW

The use of soil as an engineering material may be said to be as old as mankind itself. Since that time, man has been confronting many types of problems while dealing with soils.

Excellent pavements: **Egypt and India** much before the Christian Era.

Some earth dams have been used for storage of water in India for more than 2000 years.

During the excavation at the early civilization sites of at Mohenjodaro and Harrappa in the Indian subcontinent indicate the use of soil as foundation and construction material.

Egyptians used caissons for deep foundations even in 2000 BC.

The hanging gardens at Babylon (Iraq) were also built during the period.

The leaning tower of Pisa was also built around same time. The tower has leaned on one side because of the differential settlement of its base.

In the 17^{th} century, Leonardo da Vinci constructed a number of structures in France, and the London Bridge in England.

The Taj Mahal at Agra is built on masonry cylindrical wells sunk into the soil at close intervals.

The builders were guided by the knowledge and experience passed down from generation to generation.

In 1773, a French engineer Coulomb gave the theory of earth pressure on retaining walls. Coulomb also introduced the concept that the shearing resistance of soil consists of two components: cohesion and friction.

Darcy in 1856 gave the law of permeability. This law is used for the computation of seepage through soils.

In the same year, Stokes gave the law for the velocity of fall of solid particles through fluids. This law is used for determining the particle size.

O-Mohr in 1871 gave the rupture theory for soils. He gave a graphical method of representation of stresses. Popularly known as Mohr's circle, it is extremely useful for determining stresses on inclined planes.

Boussinesq in 1885 gave the theory of stress distribution in a semi-infinite homogeneous, isotropic, elastic medium due to an externally applied load. The theory is used for determining stresses in soils due to loads.

Atterberg in 1911, suggested some simple tests for characterizing the consistency of cohesive soils. These limits are useful for identification and classification of soils.

Prof. Fellenins (Sweden) in 1913 studied the stability of slopes. Swedish circle method for checking the stability of Sweden slopes are popularly used.

The modern era of soil engineering began in 1925, with the publication of the book, **Eradbaumechanic,** by Karl Terzaghi. He is fittingly called the father of soil mechanics.

His theory of consolidation of soils and the effective stress principle gave a new direction.

Proctor in 1933, did a pioneering work on the compaction of soils.

Taylor worked on the consolidation of soils, shear strength of clays and the stability of slopes.

Casagrande worked on the classification of soils, seepage through earth masses and consolidation.

Skempton did a pioneering work on pore pressure, effective stress, bearing capacity and the stability of slopes.

Mayerhof gave the theories of B.C. of shallow and deep foundations.

Hvorlov did a commendable work on sub-surface exploration and on the shear strength of remouled clays.

Some of the events relevant to the subject that took place in past are given below:

Table 1.1 Indian Geotechnical Conferences – Venue

1.	*1960*	*New Delhi*	*First Asian Regional Conference*
2.	1961	Bangalore	Symposium on Foundation Engineering
3.	1962-1963		During this period, Technical Sessions along with the Annual General Session were held
4.	1964	Hyderabad	Technical Session along with the 7th Annual General Session
5.	1965	Poona	Symposium on the Foundation of Power Houses and Heavy Machines
6.	1966-1967		During this period, Technical Sessions along with the Annual General Session were held
7.	1968	Talwara	Symposium on Rockfill Dams–Beas Dam
8.	1969	Ahmedabad	Technical Session along with the Annual General Session
9.	1970	Bombay	Symposium on Shallow Foundations
10.	1971	Ahmedabad	Technical Session along with the Annual General Session
11.	1972	New Delhi	Technical Session along with the Annual General Session
12.	1973	Kurukshetra	Symposium on Rock Mechanics & Tunnelling Problems was held during the Silver Jubilee Celebrations
13.	1974	Warangal	Technical Session along with the Annual General Session
14.	1975	Bangalore	Fifth Asian Regional Conference
15.	1976	Calcutta	Symposium on Foundations and Excavations in Weak Soils
16.	1977	Kanpur	Symposium on Expansive Soils
17.	1978	New Delhi	GEOCON—India Conference on Geotechnical Engineering
18.	1979	Roorkee	International Symposium on in situ Testing of Soils and Rocks and Performance of Structures
19.	1980	Bombay	GEOTECH-80 Conference on Geotechnical Engineering
20.	1981	Hyderabad	Geomech-81-Symposium on Engg. Behaviour of Coarse Grained Soils, Boulders and Rocks

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21.	1982	Surat	Conference on Construction Practices and Instrumentation in Geotechnical Engineering
22.	1983	Madras	Indian Geotechnical Conference
23.	1984	Calcutta	Geotechnical Engineering in Practice
24.	1985	Roorkee	Indian Geotechnical Conference
25.	1986	New Delhi	Indian Geotechnical Conference
26.	1987	Bangalore	Indian Geotechnical Conference
27.	1988	Allahabad	Evaluation and Applications in Geotechnical Engineering
28.	1989	Visakhapatnam	Geotechniques of Problematic Soils and Rocks
29.	1990	Bombay	Advances in Geotechnical Engineering
30.	1991	Surat	Geotechnical Analysis: Practices & Performance
31.	1992	Calcutta	Geotechnique Today
32.	1993		No IGC was held due to holding of XIII ICSMFE–94.
33.	1994	Warangal	Development in Geotechnical Engineering.
34.	1995	Bangalore	Indian Geotechnical Conference
35.	1996	Madras	Geotechnical Engineering Practice Beyond, 2001
36.	1997	Baroda	Indian Geotechnical Conference
37.	1998	New Delhi	IGC-98 & Golden Jubilee Celebrations of Indian Geotechnical Society
38.	1999	Calcutta	Analysis and Practice in Geotechnical Engineering
39.	2000	Mumbai	Millennium Conference
40.	2001	Indore	New Millennium Conference
41.	2002	Allahabad	Environmental Challenges
42.	2003	Roorkee	Infrastructural Development
43.	2004	Warangal	Ground Reinforcement Engineering Techniques
44.	2005	Ahmedabad	Geotech. Practices for Environment Management, Disaster Mitigation and Foundation Engineering
45.	2006	Chennai	Geotech. Engineering–Indian Experience
46.	2007	–	No IGC due to holding of 13th ARC
47.	2008	Bangalore	Advances in Geotechnical Engineering
48.	2009	Guntur	Geotechnics–The First Step in Nation Building
49.	2010	Mumbai	Geotrendz
50.	2011	Kochi	Soft Clay Engineering
51.	2012	New Delhi	Advances in Geotechnical Engineering
52.	2013	Roorkee	Geotechnical Advances and Novel Geotechnical Applications
53.	2014	Kakinada	Geotechnics for Inclusive Development of India

Table 1.2 International Conferences (ICSMGE)

S. No.	Year	Conference	Venue
1.	1936	I ICSMFE	Cambridge, Mass (U.S.A.)
2.	1948	II ICSMFE	Rotterdam (Netherlands)
3.	1953	III ICSMFE	Zurich (Switzerland)
4.	1957	IV ICSMFE	London (U.K.)
5.	1961	V ICSMFE	Paris (France)
6.	1965	VI ICSMFE	Montreal (Canada)
7.	1969	VII ICSMFE	Mexico city (Mexico)
8.	1973	VII ICSMFE	Moscow (USSR)
9.	1977	IX ICSMFE	Tokyo (Japan)
10.	1981	X ICSMFE	Stockholm (Sweden)
11.	1985	XI ICSMFE	San Francisco (U.S.A.)
12.	1989	XII ICSMFE	Rio De Janeiro (Brazil)
13.	1994	XIII ICSMFE	New Delhi (India)
14.	1997	XIV ICSMFE	Hamburg (Germany)
15.	2001	XV ICSMGE	Istanbul (Turkey)
16.	2005	XVI ICSMGE	Osaka (Japan)
17.	2009	XVII ICSMGE	Alexandria (Egypt)
18.	2013	XVIII ICSMGE	Paris (France)

Table 1.3 International Congress on Environmental Geotechnique (ICEG)

S. No.	Year	Conference	Venue
1.	1994	First	Edmonton (Canada)
2.	1996	Second	Osaka (Japan)
3.	1998	Third	Lisbon (Portugal)
4.	2002	Fourth	Rio De Janero (Brazil)
5.	2006	Fifth	Cardiff (U.K.)
6.	2010	Sixth	New Delhi (India)
7.	2014	Seventh	Sydney (Australia) (Scheduled)

Table 1.4 IGS–Kuecklemann Award

S. No.	Years	Awarded to
1.	1986–87	Prof. R.K. Katti
2.	1988–89	Prof. T. Ramamurthy & Shri C. Sudhindra
3.	1990–91	Prof. T.S. Nagaraj & Prof. Gopal Ranjan
4.	1992–93	Prof. A. Sridharan & Prof. Shashi K. Gulhati
5.	1994–95	Dr. Narayan V. Nayak

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6.	1996–97	Prof. M.R. Madhav & Prof. K.S. Subba Rao
7.	1998–99	Dr. R.K. Bhandari & Prof. G.V. Rao
8.	2000–01	Prof. N. Som
9.	2002–03	Prof. A.V. Shroff & Prof. B.R. Srinivasa Murthy
10.	2004–05	Prof. Shamsher Prakash
11.	2006–07	Prof. Swami Saran
12.	2008–09	Prof. V.S. Chandra Sekharan
13.	2010-11	Dr. V.V.S. Rao & Dr. Mahavir Bidasaria

Table 1.5 Asian Regional Conferences

S. No.	*Year*	*Conference*	*Venue*
1.	1960	1st ARC	New Delhi (India)
2.	1964	2nd ARC	Tokyo (Japan)
3.	1967	3rd ARC	Haifa (Israel)
4.	1971	4th ARC	Bangkok (Thailand)
5.	1975	5th ARC	Bangalore (India)
6.	1979	6th ARC	Singapore
7.	1983	7th ARC	Haifa (Israel)
8.	1987	8th ARC	Kyoto (Japan)
9.	1991	9th ARC	Bangkok (Thailand)
10.	1995	10th ARC	Beijing (China)
11.	1999	11th ARC	Seoul (Korea)
12.	2003	12th ARC	Singapore
13.	2007	13th ARC	Kolkata (India)
14.	2011	14th ARC	Hong Kong
15.	2015	15th ARC	Fukuoka/Japan (Scheduled)

Table 1.6 IGS-AIMIL Best Local Chapter Award

S. No.	*Year*	*Awarded to*
1.	1995	IGS Delhi Chapter
2.	1996	IGS Baroda Chapter
3.	1997	IGS Mumbai Chapter
4.	1998	IGS Indore Chapter
5.	1999	IGS Baroda Chapter
6.	2000	IGS Calcutta Chapter
7.	2001	IGS Mumbai Chapter
8.	2002	IGS Indore Chapter
9.	2003	IGS Allahabad Chapter
10.	2004	IGS Roorkee Chapter

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