HASAN KALYONCU UNIVERSITY
GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES

USE OF GIS FOR EVALUATING THE GEOTECHNICAL PROPERTIES IN KAHRAMANMARAŞ, TURKEY

M.Sc. THESIS
IN
CIVIL ENGINEERING

by
Abdullah CANBOLAT

2017

Use of GIS for Evaluating the Geotechnical Properties in Kahramanmaras, Turkey

M.Sc. Thesis
in
Civil Engineering
Hasan Kalyoncu University

Supervisor
Assist. Prof. Dr. Şafak. TERCAN

by
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2017

REPUBLIC OF TURKEY
UNIVERSITY OF HASAN KALYONCU
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES
CIVIL ENGINEERING DEPARTMENT

Name of the thesis: Use of GIS For Evaluating the Geotechnical Properties in Kahramanmaras, Turkey

Name of the student: Abdullah CANBOLAT

Exam date: 07/11/2017

Approval of the Graduate School of Natural and Applied Sciences

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Abdullah CANBOLAT

ABSTRACT

USE OF GIS FOR EVALUATING THE GEOTECHNICAL PROPERTIES IN KAHRAMANMARAŞ, TURKEY

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June 2017, 66 Pages

This study presents a Geographical information System (GIS) application for evaluating geotechnical properties in Kahramanmaraş city, Turkey. Geotechnical investigations in the city were carried out both in situ and laboratory. 287 boreholes in the city were drilled in order to perform Standard Penetration Tests (SPT), and to define the physical properties of the soils obtained from these boreholes. In this study, maps for SPT-N, bearing capacity, liquefaction potential, Soil water table, and (V_{s30}) have been produced by using a GIS based computer software. Accordingly, it is expected that the complied GIS maps could be effectively used by researchers and engineers for further studies on the purpose of urban planning.

Keywords: GIS, geotechnical properties, Kahramanmaraş.

ÖZET

KAHRAMANMARAŞ' TAKİ ZEMİNLERİN GEOTEKNİK ÖZELLİKLERİNİN CBS İLE DEĞERLENDİRİLMESİ

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Haziran 2017, 66 Pages

Bu çalışmada Kahramanmaraş'ın zemin özelliklerini içeren coğrafi bilgi sistemi (CBS) sunulmuştur. Zemin araştırması hem arazide hem de laboratuvarda yapılmıştır. Şehrin 287 adet sondaj noktasından alınan numunelerin Standart penetrasyon testleri (SPT) ve diğer fiziksel özellikleri elde edilmiştir. Bu çalışmada SPT-N, taşıma kapasitesi, sıvılaşma potansiyeli, yeraltı su seviyesi, su muhtevası, ince dane oranı ve dalga kesme hızı ($V_{s30)}$ haritaları CBS temelli yazılımlarla üretilmiştir. Bu bağlamda zemin tahkiklerine ilişkin veriler şehir planlama ve diğer mühendislik çalışmalarında daha etkin ve verimli olarak kullanılabilecektir.

Anahtar Kelimeler: CBS, geoteknik özellikler, Kahramanmaraş.

ACKNOWLEDGEMENTS

I would like to thank my Assoc. Prof. Dr. Ali Fırat ÇABALAR, Assist. Prof. Dr. Şafak Hengirmen TERCAN and instructor. Nurullah AKBULUT for their invaluable helps during my MSc studies.

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ABBREVIATIONS OR SYMBOLS LIST

a_{maks}	: Greatest Soil acceleration
C_N	: Overburden correction in SPT experiment
C_E	: Stem bar nergy ratio correction in SPT experiment
C_B	: Well diameter correction in SPT experiment
C_R	: Stem bar length correction in SPT experiment
C_S	: Inner tube correction in SPT experiment
CRR7_5	: Neccessarry repeated stress ratio for Soil liquefaction (for a 7.5 scale earthquake)
CSR	: Repeated stress ratio created by earthquake
Er spt	: Stem bar energy ratio for SPT experiment
g	: Gravity acceleration (cm/sec^2)
H	: Level thickness (m)
LPI	: Liquefaction potential index
Ms	: Scale of earthquake (surface waves)
MSF	: Earthquake scale correction coefficient for security coefficient against liquefaction
N	: Number of strikes from SPT experiment
N_{60}	: Corrected strike number prior to energy ratio
$(N1)_{60}$	: Corrected strike number considering all
$(N1)_{60cs}$	: Corrected strike number according to fine pieces ratio for liquefaction analysis
Pa	: Athmospheric pressure (100 kPa)
R	: The length of earthquake centre from research area (km)
Rd	: Stress decreasing factor
WB	: Well bore
SPT	: Standard Penetration Test
z	: Depth below surface (m)
σ_{vo}	: Total cover stress (kPa)
q_d	: Soil bearing capacity (kg/cm^2)
σ'_{vo}	: Effective cover stress (kPa)
α, β	: The coefficients to correct $(N_1)_{60}$ based on fine content
τ_{av}	: Average horizontal shear stress

CHAPTER 1

INTRODUCTION

1.1. RESEARCH AREA

In this thesis, it was aimed to study the bearing capacity of soil, liquefaction potential, shear wave velocity (V_{s30}), Standard Penetration Tests (SPT), Soil water table values using data obtained from the works carried out by the Kahramanmaraş Municipality. The thesis shows how to adapt geographically information systems (GIS) into geo-technique in terms of Kahramanmaraş. First, a geo-technical database for Kahramanmaras city was made by combining field and laboratory data obtained from boring logs. Then, a GIS application was established to indicate analysis results of those data (İller Bankası; 2004).

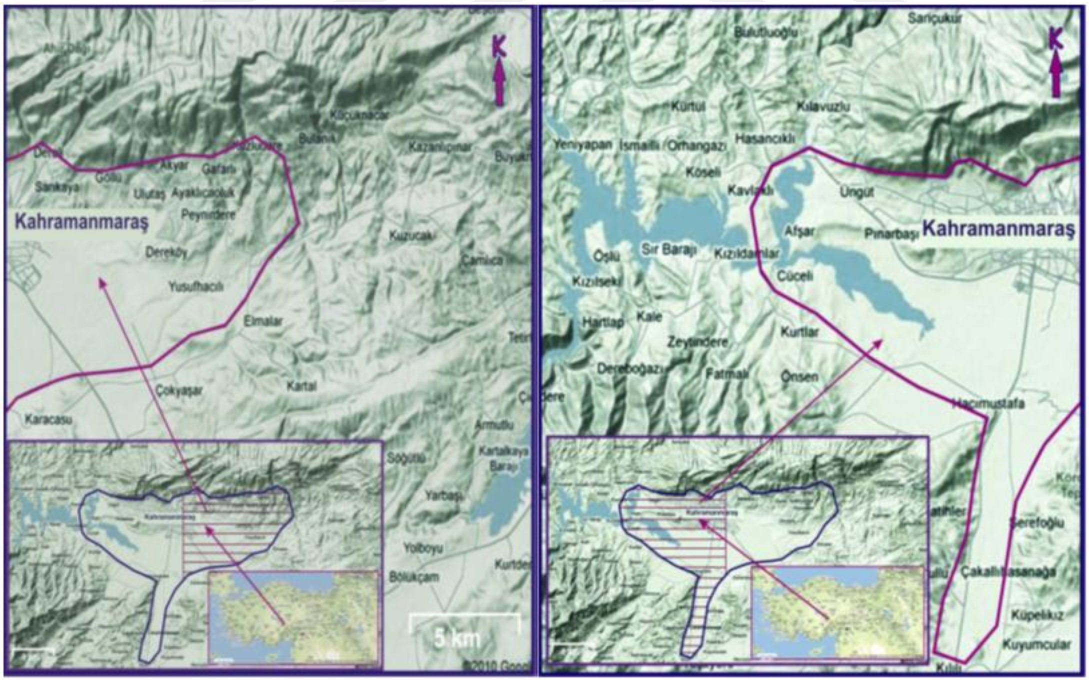


Figure 1.1. The Map of Study Area

Kahramanmaraş is bourdered by neighbor cities Sivas and Malatya are located in the north of Kahramanmaras city, while Kayseri is located in the north-west, Adana is located in the west, Osmaniye is located in the south-west, Gaziantep is located in the south and Adıyaman is located in the east of Kahramanmaras. The city has nine neighbor; Goksun and Ekinozu are in the north, Nurhak and Caglayancerit in the east, Pazarcık and Turkoglu in the South and Andırın in the west, Afsin and Elbistan are in the North.

In the South of research area at about 451 m high there are alluvium straights of Maras plain while in the North at about 1300 m high there are highlands of Ahir Mountain which surround the city from east to west. Kahramanmaras is a tectonic based alluvium plain whose boundaries are under the control of fault lines. The length of Kahramanmaras plain laying between Cimen and Ahir Mountains is 40 km, the width from north to South is nearly 20 km.

Ceyhan River flows from North to South limiting the research area. On the other hand, Aksu River, one of the sub branches of Ceyhan River of which total length is 509 km, surrounds research area from South to North and terminates at Sır Dam. There are also little streams in the city like Delicay, Erkenez, Peynirdere, Kerhan and Kozludere.

In the North of the city there are karst lakes, Karagol and Kucukgol at the Ahir Mountain; Humaşır lake, an older meander of Aksu river. In the west of the city there are Sır Dam, built for energy production, on Ceyhan River; in the east Ayvalı Dam being built for water supply on Erkenez stream and in the North-west Kılavuzlu Dam being built for energy production (İller Bankası; 2004).

The neotectonic regime of Turkey is mainly controlled by the continuing northward motions of the African and Arabian plates with respect to Eurasian plate, which began in the Middle-Late Miocene and resulted in the westward extrusion of the Anatolian block along the North and East Anatolian fault zones, the study area, which is the southeast Anatolian orogenic belt, comprises different tectonic units with various lithological sequences.

Upper Paleozoic carbonate and clastic rocks and Jurassic-Cretaceous limestone (Taurus units) occur in the west of the Amanos Fault, the western part of the study area. The eastern part of the study area consists of a nappe region in the north and an imbricated zone and Arabian platform in the South.

The Arabian Platform in the study area comprises, from bottom to top, Triassic-Cretaceous pelagic limestone, radiolarite, chert, clastic rocks, volcanic rocks and local ophiolitic sheets, Upper Cretaceous clastic and carbonate rocks, Upper Paleocene-Eocene volcanic and sedimentary rocks, Eocene clastic rocks and neritic limestone, upper Eocene-Lower Miocene volcanic and sedimentary rocks, Lower Miocene clastic rocks and neritic carbonates, Middle-Upper Miocene neritic carbonates, and continental clastic rocks. Plio-Quaternary neotectonic continental rocks uncomformably overlie these older rock units.

The Kahramanmaras¸ basin is located near the triple junction of the Arabian, African and Anatolian plates. As a result of the collision of Arabia and Eurasia along the Bitlis Suture a trough formed in front of the thrust sheets and was consequently filled by thick alluvial sediments and thick turbiditic flyschsequences..the Kahramanmaras¸ basin was part of this elongated foreland basin extending from Hakkari in southeastern Turkey, close to the border to Iran and Iraq, to Adana in southern Turkey.

Eocene deposits in the Kahramanmaras¸ area are part of the Arabian Platform.-they indicate a shallow marine depositional environment with local terrestrial input followed by allegedly lower to middle Miocene reefal limestone and claystone. Oligocene bioclastic limestones are reportedonly from the margin of the Kahramanmaras¸ area.

Basal shallow marine red-bed and basalt sequences of the Kalecik Formation have an inferred age of late Burdigalian to Langhian. The retreat of marine conditions and basin deformation was assumed to have taken place in the late Miocene, although the age control was not documented.-Three separate sections all north of the city of Kahramanmaras¸, are been studied by us. The lower 200 m were sampled in the hills in the southern part of the main basin (Hill section), the following about 4.6 km along the road north of Kahramanmaras¸ the base of the Hill section consists of nummulitic limestones according to the Geological Map of Turkey of Eocene age, followed by red, conglomeratic sediments with several basalt layers.

The studied section begins with a 200 m thick succession of nodular limestone alternating with bluish marls. The limestones contain macrofossils such as corals, sponges, echinoderms, bivalves and gastropods, indicating a shallow marine environment. This succession grades into an alternation of marl and sandstones layers, which show typical Bouma sequences and flute casts--the base of the Road section, however, exposes a strongly different succession, where almost 1 km of the stratigraphy is dominated by large conglomerate lenses. This thick succession of conglomerates contains sand lenses showing cross bedding, indicative of interfingering of braided river channels. This thick fluvial succession probably forms, at least in part, the lateral equivalent of the shallow marine succession in the Hill section. This conglomeratic succession is followed by a level rich in oysters, indicating a transition into shallow marine conditions. This then grades quickly into a very thick succession of alternating marl and sandstone (as mentioned above) with occasional conglomeratic layers, interpreted as debris flows, which cut through the stratigraphy. The sandstones show typical characteristics for turbidites, such as flute casts and Bouma sequences. Some intervals are dominated by massive sandstone layers and/or debris flows, while others are characterized by mainly clay.

CHAPTER 2

LITERATURE REVIEW AND BACKSOİL

2.1. GEOGRAPHICAL INFORMATION SYSTEMS

2.1.1. Introduction

Information is not well-organized and in time the emergence of such dense information has lead the society especially those who are in decision making position into a chaos and panic situation (Yomralıoğlu, 2000).

At our age, information technology serves humanity in many different means. The GIS, plays a vital role especially in managing space, Soil and location related information or managing and combining complex.

As the users vary at a large range from different disciplines, the GIS is defined in many terms. GIS is a system collecting, storing, controlling, processing, analyzing and screening earth related data (AGI, GIS Dictionary, 1991). It is all the tools used to collect, store, search, transfer and screen earth related data (Burrough, 1998). GIS is an information system collecting graphical and non-graphical data, storing, analyzing and putting them in front of the users as a whole. GIS is sum of systems to enable searching and analyzing positional and non-positional information relating them to each-other (Figure 2.1.).

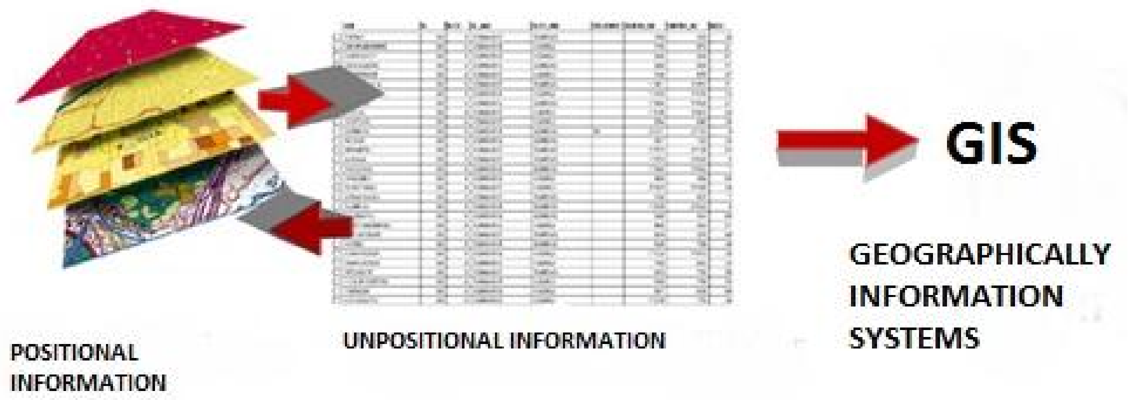


Figure 2.1. Positional and Non-Positional information (Şen, 2004)

There is an effective communication structure between graphical and non-graphical information (Şen, 2004).

GIS prior to application processes;

- Urban information Systems
- Land information Systems
- Cadastral information Systems
- Market Analysis information Systems
- Natural Resource Management information Systems

GIS is related to positional data processing techniques. Besides bellow there are given different names of GIS (Şen, 2004);

- Computer Aided Design, CAD
- Computer Aided Cartography
- Data Base Management Systems, DBMS
- Remote Sensing

2.1.2. The Functions of Geographically information Systems

Geographically information Systems are perceived as the systems composed of computer aided tools necessary for transforming earth shapes and event into map and analyzing them. The GIS technology has the capability of combining common databases. For instance, the advantages of visual and geographic analysis supplied by maps are presented to users as searches and statistical analysis. the GIS is different from any other information systems with regard to this feature. As a result of this, GIS, is widely used by both public and private sector in defining events in service field and making strategic plans by estimating future (Yomralıoğlu, 2000).

There are functions of GIS which differ from the rest, behind all these developments. These functions are given below.

2.1.2.1. Combining Numerical Data

The GIS, can work in accordance with numerical and verbal data created in different circumstances. For example, graphical data or visual data such as photographs and etc created by CAD softwares; tables or lists in databases can be taken as input by GIS or similary the data created by GIS can be used as input by other softwares. Thus, GIS makes the integration between numerical data, namely data exchange, easier.

2.1.2.2. Positional Searching

In many cases, database management systems are used to reach the geographical data collected before for possible future need. However, it is only possible with GIS to see and search graphical and non-graphical data together. You can reach from graphical information to defining information or likewise from defining information to graphical information rapidly with GIS. (Şen, 2004).

2.1.2.3. Automation

The GIS provides its users a type of automation, computer aided calculating, in works needing measurement and calculations. That all sort of calculations and graphical drawings can be made rapidly and truly at the same time and Soil.

This feature of GIS has helped these maps including numerical data to improve and lead them to be called as "Smart Maps". Many classical measuring techniques such as using ruler and other tools on paper maps have been replaced by modern technique, using cursor on computer to calculate necessary things. The clear position of any point on a map or plan, the distance between points or space are transferred to user dynamically by just moving the cursor. By means of automation feature, complex calculations on map, regulating the objects and improving the quality of cartographic presentations are ensured.

2.1.2.4. Imaging

One of key features of the GIS is imaging. Today, it is possible to add any sort of visual effects, graphical information, video, audio, photographs etc. to presentations on which once only non-graphical table-like information were presented supplied only by certain databases. However, while presentation could only be done on paper, today it is possible to exchange information on internet or similar platforms by transferring these data on numerical Soil.

A type of visual qualification by relating table reports to images has been gained to positional information in terms of trade, tourism, real estate dealing and statistics (Şen, 2004).

2.1.2.5. Information Management

One of the main problems for those dealing with positional data is not being able to realize updating, sorting, adding, transferring and similar actions. However, GIS has the capability of data handling faster than expected if it is essential. So that new information can be produced from old data in any desired format and transferred to different systems. With regard to this feature of GIS, updating current data and generalizing them when it is necessary.

2.1.2.6. Positional Analysis

All modeling graphical or non-graphical information by means of objectives and interpreting the results are known as the "Positional Analysis". One of the main features of GIS, at the same time distinguishing it from similar information systems, is its positional analysis future.

In positional analysis actions, all types of applications such as producing new information sets from old ones, evaluating potential uses of geographic scopes, estimating potential effects of positional events on environment and interpreting these events and making them easily tangible. As an example for the positional analysis- most important feature of GIS, is that combining different maps into one (one map for city's architectural structure and another for geological identity), defining a scope for flooding area along a river, identifying legal successors of an area or position based analysis to define addresses in a city (Yomralioglu, 2000).

2.1.2.7. Decision Making Analysis

Besides basic statistical analysis, GIS becomes much more dynamic in estimating future from current data, deciding areas for investment, locating tools on where it is most suitable for planning, processing data statistically, operational research, following positional specifications based on time and decision making analysis for answering all "why" questions. GIS collects these data and fulfills an important role to make graphically enriched positional information clearer by classifying them according to pre-decided criteria.

2.1.2.8. Model Analysis

Observing some projects or situations emerging as a result of natural events as if it really happened before is known as "simulation". GIS has the ability to realize simulations with models created on computer and considering geographical items' relations with their environment (Şen, 2004).

For example, because of the fact that the estimated data to be collected for an earthquake, erosion, flood habits, projecting road, railway and pipeline, and finally planning a new settlement are all coordinate based their numerical area models can be created on a computer and all changes can be seen easily on computer.

As GIS is able to include both graphical and descriptive data on its database, any sudden change can be observed on created model so that it can help user on decision making process. Thus, this identified project as if it is real, can provide enough information to managers and experts about their special project (Şen, 2004).

2.1.3. The Components of Geographical information System

At least five components should be together for GIS to fulfill its basic functions (ESRI inc., www.esri.com). These are called as the components of GIS – equipment, software, data, human and methods.

2.1.3.1. Equipment

Computers and other supporting tools are known as equipment. Besides computers, to work, there is also a need for other supporting tools. Today, most of GIS software can work on different equipments. Also there are different equipments from centralized computers to desktop computers and from personal ones to network supported ones.

2.1.3.2. Software

Software, a program which can work on computer is highly created by algorithms through programming languages in order to supply some functions and needs like storing, analyzing and displaying geographic information.

Although most of the programs have been developed by some companies for commercial purpose, there are also programs developed by universities for research activities.

An important partion of GIS software is market controlled by commercial software companies throughout the world. Thus, it can be said that today GIS is almost synonymous with such softwares. The most popular GIS programs are Arc/info, intergraph, Maplnfo, SmallWorld, Genesis, Idrisi, Grass. Some of the most basic features for any geographically information system are as follow (Şen, 2004).

- Including necessary tools to enter geographic information/data
- Having a database management system
- Supporting positional inquiry, analysis and image
- Having interface support for additional tools' connection

2.1.3.3. Data

Data, is another most important component of the GIS. While it is possible to collect geographic data, descriptive information or table-like ones from related sources also these can be bought from market. The GIS can combine positional information that different information for various organizations and institutions can be organized and positional data can be unified.

While data are accepted as the basic component for GIS by experts, at the same time it is also accepted to be the most difficult component to obtain. A great deal of time and cost is needed to collect these data because of data sources' being separate, numerous and different structures. Eventually, nearly % 50 of the total cost essential for building a GIS system is for data collection (Aydan and frd, 2000a).

2.1.3.4. Humans

The GIS technology will be limited without human beings. Because humans manage necessary systems and prepares development plans to apply real world problems. GIS users are a huge society, expert technicians who design systems and protect, and people who use it to increase their performance on their daily duties. So it can be concluded that in GIS there are people who have some needs and people who try to answer these needs. It can only be possible to develop GIS by means of people's developing their abilities for using it with positional analysis in almost every suitable discipline and introducing its advantages to other people (Aydan and frd, 2000a).

2.1.3.5. Methods

These functions are models to fit any organizations and applications. It is essential for GIS to develop and apply methods to provide efficient positional information flow among different units of organizations and between different organizations. Obtaining positional information, producing and presenting them needs to be user-friendly in a proper way based on some rules and standards. These applications, which are generally defining standards, are directly related to organizational structure of the institution. Thus, some official procedures are applied and necessary regulations are made (Demirtaş and Yılmaz, 2002).

2.1.4. How GIS Works?

GIS stores information about earth by accepting them as geographically interrelated map layers. This is simple but ultimately stronger attitude for evaluating positional information. This attitude enables solving daily life problems from calculating optimum distribution for carriers to modeling changes at the atmosphere (Demirtaş and Yılmaz, 2002).

2.1.4.1. Geographic References

Geographic information includes certain data such as coordinate values like latitude and longitude or descriptive data such as described reference info like address, road or area codes. These geographic references facilitate objects to be positioned, to put on a coordinated position. So that trading zones, areas, forests, earth's surface movements and terrestrial objects' analysis are defined due to position. While identifying geographic reference position, location data namely coordinate info is selected and defined according to data model (Burrough, 1998).

2.1.4.2. Basic Functions

Healthy functioning of GIS depends on fulfilling these basic functions;

a) Data collection
b) Data management
c) Data manipulation
d) Data display

2.1.4.2.1. Data Collection

Geographic data should be collected and before using them in GIS they must be transformed into numeric, digital format. The process of transforming data from paper or map into computer is known as digitizing. In the modern GIS technology, such operations are realized through huge projects by using scanning techniques. Whereas in smaller projects, digitizing is realized via manual numerical techniques by using desk type digitizing machines. Nowdays most of the geographic data is compatible with the GIS and can be found in market. They can be provided from markets and directly transferred into system (Demirtaş and Yılmaz, 2002).

2.1.4.2.2. Data Management

In small size GIS projects, it is possible to store geographical information in small size simple files. However, in large scale GIS projects, where data is huge and detailed and more than one group of data is used, Data Base Management Systems help to store, organize and manage data. Data Base Management Systems are computer sofwares and manages databases or unifies them. There are various types of database management systems but the most suitable one for GIS is relational one. In this system, data is saved in computer memory. (Şen, 2004).

2.1.4.2.3. Data Processing

In some cases, for GIS projects data types are requried to be transformed into each other. For example, positional values will be in different scales (road information 1/100000, population data 1/10000, buildings 1/1000 etc.). All these data before uniting them should be tranformed into same scale (Yomralioglu, 2000). This transformation can be instant for imaging or permanent for analysis (Burrough, 1998).

GIS provides basic inquiry capacity by just clicking cursor on object at computer screen and information to managers and researchers through positionals analysis tools. Then, today GIS technology has reached at point where geographical data and scenarios are questioned with statistical graphics and “if” conditions. In GIS technology, inquiring and analyzing positional data can be done by means of processing various data in any type of geometrical and logical steps (Şen, 2004)

2.1.4.2.4. Data Display

Visual operations are again one more important function for GIS. The things at the end of numerous geographic processes are visualized by means of maps and graphics. Maps are the best tool to facilitate communication between users and geographic information. Maps can be combined with reports, 3-D displays, photographs, multimedia products.

2.1.5. Data Models in Geographic information Systems

In order to process real world geographic entities in a healthy and fast way, these entities are required to be transformed into mathematical statements and transferred into computer at once. For transforming, first of all data should be classified in two what as graphical and non-graphical. Then graphical data are defined as geographic elements such as points, lines and polygons. So that coordinate info can easily be transferred in computer. On the other hand, non-graphical values of geographic data are table-documents and these can easily be transferred as textual statements. (Aydan and frd., 2000a).

In next step, users are provided numerical interpreting chance similar to visual maps do by building a link between two different data group. This depends on reflecting real world geographical data model, like in reality, by digitalizing.

The emergence of geographical data models depends on how they are obtained. For example, a city's geographical data can both be on classical paper maps and on satellite photos. So obtaining methods for these two different data groups are different then they need to be transferred into computer and modeled due to differences.

Transferring geographical data, processing them on computer and displaying can only be possible through transforming this raw data in numerical type, in other words through digitalizing them. Moreover, in order to use these digitalized data on real models, one of the positional data models should be preferred and data structure must be designed accordingly. Positional data models are in two ways in GIS (Burrough, 1998);

a) Vector data model
b) Raster data model

2.1.5.1. Vector Data Model

Geographic data, in vector data model, seems like a map. Within this image, points represent permanent areas, small sized images, lines represents areas and continuous geographic shapes while polygons represent homogenous structured large geographical shapes. Polygon means multi-edged. Sometimes it is called space. It consists of many edges.

It can be concluded that series of points make lines, and series of lines make polygons. Reverse, from polygons we can make lines.(Şen, 2004).

The real position of a geographic shape on a model is shown by a reference based coordinates axis (x, y) values. In vector data model, each geographic shape has x-y coordinate. While points are represented with a single coordinate, lines and polygons are represented with series of coordinates. But the beginning and ending coordinates of a polygon are which it differs from lines (Burrough, 1998).

In vector model, points, lines, polygons are saved by being coded in coordinate values (x, y). While an electric transmission tower is shown as a point with one x-y coordinate value, a road or river is shown as a line with a series of coordinate values (x_1, y_1), (x_2, y_2), (x..., y...), (x_n, y_n) . Buildings, areas, forests or lakes is shown as polygons by a series of coordinate values of which initial and final values are the same as in (x1, y1), (x2, y2), (x. , y.), (xn, yn), (x1, y1).

Vector model is really a useful model in identifying clear locations of geographic shapes. But, it is known as useless in identifying continuous things such as soil structure, flora, geological feature and surface qualifications (Şen, 2004).

Geographical entities are represented by coordinates with numeric values without using images or graphics.

2.1.5.1.1. Storing Vector Models on Computer

Each geographic entity is addressed by a unique identity number separates from all others in order to distinguish each from others and reach easily when it is essential. This number is called “code number” or “identification (ID)”. A code number, once defined, is associated with the coordinate values identifiying geographic entity it shows which coordinate value belongs to which geographic entity. After geographic elements with points, lines and polygons are defined with coordinates, with the help of code numbers for each element, these data are transferred to computer via basic table based databases (Burrough, 1998).

While vector data saves coordinate values of geographic element’s structure, there is a need for the use of computer memory depending on the size of data. The memory need varies on the types and numbers of geographic elements, so the memory need changes according to data size. Line- node data structure is based on the principal of lines created by nodes. Nodes create polygons. Nodes are the edge points at the beginning and ending of lines. Nodes are not always at the edge, but any single point can also be called as node (Burrough, 1998).

Line is defined as the continuous row between two nodes. A line creating a row by being between two nodes is sum of segments following each other. The cut point for each segment is called vertex. Vertexes are beginning and ending points whose coordinates are known and shape the line they create (Demirtaş and Yılmaz, 2002).

To make the applied line-node data structure in order to save vector models by spending these data can be saved on computer in two ways (Yomralioglu, 2000). These are "spaghetti data structure" and "topologic data structure".

2.1.5.1.1.1. Spagetti Data Structure

In this data structure, map on paper context is transferred to coordinate series with lines. Geographical entities are saved and represented by likening them one of the point, line or polygons. Point like figures are shown as one unique coordinate value while lines or polygons are stated as a series of coordinates (Demirtaş and Yılmaz, 2002).

Within this data structure, entities or details can be coded according to their classes. Common boundaries are saved at least two times on computer in spaghetti data structure. Thus, it is not an optimum way of saving or showing data. However, saving and showing are done by protecting the real shape of geographical entity (Şen, 2004).

Continuous structures are thought as separate from each other in geographic data elements. For example, the cut point for a river and road is disregarded and both are shown as continuous entities. The final structure is called spaghetti data structure. In spaghetti data structure, while coordinate values and detail codes for all details are recorded, the neighborhood among these details, right-left direction information or in-out location information are not recorded. This feature is the most known thing to distinguish spaghetti data structure from topological one. Spaghetti data structure is inadequate in calculating many positional analysis as it requires calculation to define many positional relationship. But it is highly effective in creating numerical maps because it doesn't record positional relationships which are not necessary for drawing job (Demirtaş and Yılmaz, 2002).

2.1.5.1.1.2. Topological Data Structure

Although topology is known as a mathematical branch dealing entities relationship with each other rather than their metrical information; in GIS toplogy is defined as showing how and in what way entities are interrelated separately from geometrics. There is graph theory, a mathematical theory, under topology. According to graph theory details occurs when two sets combine; these are node set and line set. Node set include limited element and can not be empty which means at least one element is in it. Line set includes limitless elements and it can also be empty, which means there will be no element in it. But if line set has one element, this will be sum of two elements of node set (Yomralioglu, 2000).

It is possible to observe and interpret the relationship between different geographical entities by using the information on a map. For example any tourist who has basic map knowledge can easily use a map and reach the museum he wants. Throughout this activity neighborhood relations of details on destination are considered rather than metric size information of details. At this point using a map is just like somebody's giving direction. For example the statements like "Turn left after hotel gate and walk until you see post office, then turn right and go straight to find tower and you will see museum between town hall and bus stop opposite to tower" are also defining the topologic structure of the map (Şen, 2004).

The geometric representation of geographic entities are stable shapes of these entities with space coordinates and the relationship of entities can only be shown with coordinate values. Topologic representation is somewhat a deformed and much more elastic version of geometrical representation. Topology doesn't deal with entities' size or structure but with the basic features still standing after deformation. Topology's contributions can be summarized as follow; (Aydan and frd, 2000a).

1. It helps to define entities' relations (crossing or neighborhood) easily in order to reach data quickly.
2. In crossing definitions, common line or node is identified just one thus it decreases data amount by saving common details together.
3. It helps navigation during geometrical data.
4. It enables geometrical data's being coherent.

Topology mentality is one of the most important functions of softwares designed for GIS. The greatest cause for need of topology in GIS software is to be able to realize modeling connections at a web prior to their direction and connection points, analyze neighborhood relations of similar polygons and geographical features without any need of coordinate values.

In GIS there are three different topological data structure to fulfill basic topological functions. These are arc-node topological data structure, polygon-arc topological data structure and left-right topological data structure (Aydan and frd, 2000a).

2.1.5.1.1.2.1. Arc-Node Topological Data Structure

It is a topologic data structure recording connectivity at computer. Connection provides information about how rows follow each other on a destination and their connection points. For example; road and street crossings, underway and railway connections, sewerage, water, electric, telephone rows and river-road crossings. Connection structure is stated by means of arc-node topological data structure. Each arc consists of two nodes. According to arc's beginning and ending situation, a list showing flow as "from node" or "to node". All arcs combines at a node (Şen, 2004).

2.1.5.1.1.2.2. Polygon-Arc Topological Data Structure

It is a topological data structure recording area definition on computer. Area, also known as polygon, is a closed shape and it is defined and limited with the arcs surrounding it. Polygon-arc topology, to some extend, provides relations between closed areas and their surrounding arcs. For example, a road limiting a lake, sea limiting an island, boundaries limiting an area and finally the line separating two districts

Area defining structure is stated with polygon-arc topological data structure. Each polygon consists of coordinate series following each other. In polygon, beginning and ending points are the same and it forms a closed shape. This closed shape has area information. However, in polygon-arc topology, the arcs surrounding polygon are taken into consideration instead of coordinate values. Thus, a list of surrounding arcs for each numbered polygon is done. This attitude, especially prevents repeating coordinates for polygons sharing same boundary and polygon crossing. If it is expected that there are long and complex boundaries between polygons, with polygon-arc topological attitude the arc coordinates in this boundary shall be recorded in computer memory once (Burrough, 1998).

2.1.5.1.1.2.3. Left-Right Topological Data Structure

It is a topological data structure recording the contiguity between geographical entities. This neighborhood process, contiguity, consists of information about neighbor polygons surrounding polygons. Because of the fact that each arc has beginning and ending points then it means that the flowing direction is known. Then, it is possible to address the polygons on the left and right hand side of each flowing arc. Meanwhile, with contiguity topology, farm lands around a forest, areas around a lake, buildings beside a road and roads, rivers etc. separating polygons can be scanned. This contiguity is stated with left-right topological data structure. In left-right topological data structure, neighbor polygons share the arc between them (Burrough, 1998).

2.1.5.2. Raster Data Models

Another data model to display geographical features is known as raster data model. While vector data display is arc-representation of features on a map, raster display is something as if taking a photo of similar geographical features. When such a photo is examined thoroughly it can be seen that there are numerous small colorful squares. In raster model, having a photograph specification, any singular image consists of a series of small squares also known as pixel or cell or in other words grids. Grids are the same size, but they can be both same color and similar tones of a color (Şen, 2004).

In raster displaying, there isn't any boundary between two geographical entities having different features, instead there is a continuous displaying. Distinguishing different features occurs when the colors or at least the tones differ. Thus, each of the pixels has unique color codes in order to reflect its basic features and be distinguished from others (Burrough, 1998).

Entities are appointed to color values on scale according to colors they reflect and information they posses. This color scale is called "color" or "image depth". For example, in a map with raster displaying, roads can be shown with light grey while buildings are shown with dark grey and playSoils are shown with much lighter grey. These displaying are qualified to effect image quality according to desired sensitivity. The power of entity for reflecting reality on the map, in other words the sensitivity, depends on map scale or the quality of image taking. In raster display, this sensitivity is measured with pixel size or resolution. While the size of pixels are measured in micron scale on computer, in reality it can be measured with meter or centimeter unit. The real size of pixels are called earth-resolution (Aydan and frd, 2000a).

2.1.5.2.1. Recording Raster Model on Computer

In order to record them on computer, raster data model need coordinate information as it is the case for vector models. In raster data model, each location is stated by a pixel. In such raster displays, while the coordinate information of each cell is defined with row and column number; the beginning for the coordinate is always taken as the left upper corner. The horizontal axis (column) is called X, while the vertical axis (row) is called Y. (Şen, 2004).

Whereas the whole or a part of raster based map is defined with pixel matrix created by horizontal or vertical rows and columns, such display is also known as grid model. Each pixel or cell on grid, has nominal value prior to geographical value it carries. This nominal value can either be a code used for area identification or a color scale value between 0-255. (Aydan and frd., 2000a).

As in vector display, the displays of point, line or polygon elements are also possible with raster data model. Point is shown with one pixel on grid, line is shown with a series of linear pixels while polygons are shown with a group of pixels which are neighbor to each other (Aydan and frd., 2000a).

While the changes in line width in vector data model can change image sensitivity, in raster model pixel size effects image sensitivity. Again in vector model, a continuous line's width can change, in raster model such a thing doesn't seem possible. The pixel size is constant and the whole of a cell has to carry the same geographic feature. Thus, in raster display, finding pixel size at the beginning carries great importance (Aydan and frd., 2000a).

In raster displays, the areas where pixel size is smaller is much more sensitive than those where pixel size is bigger. While the bigger pixel size corrupts image quality it also decreases the necessary memory at the computer to be recorded. In other words, we need much more space for highly sensitive images. The more pixel size is smaller, the clearer images become and the more color depth is the more authentic the images become. The most common color depth used today is such; if we accept a map with size 50 x 70 cm is represented on computer with 0,1 x 0,1 mm pixels, there will be 35 millions of elements on one unique map layer's matrix. When only 1 byte is used for one element the layer will take 4 MB, if 8 byte is used then the need will rise to 33 MB. When we consider different layer need for the same region then a huge amount of memory need will arise. If a pixel shows 250 x 250 m area on the map then a 1 km length area will take 4 pixels. Similarly, 1 x 1 km area will take 16 pixels. If it is desired to be much sensitive, for example if 100 x 100 m takes one pixel, then we need 10 pixels for 1 km length and 100 pixels for 1km^2 area (Şen, 2004).

In order to rise displaying capacity of raster data structure, pixel size should be decreased or color depth should be increased. But raster display spends more memory on computer than the vector technique does. Especially the empty areas in vector data display have to be shown at raster display and recorded in memory as they are regarded as not empty. For example each of the values in a series like 111110000111000 should be recorded in memory. However basically, such a series of value can be shortened like 51403130 (8 characters). Although this attitude is the simplest raster data zipping technique, some different zipping techniques are also used for raster data structure.

There are also some superiorities and negative sides of methods used for recording raster data structures on the computer. The fact that each pixel has different value or feature in raster method, it becomes much more difficult to simplify a "m-n" series of data. Thus the size of data and memory need are important factor. In cases when thematic maps have homogeny distributed areas, it is possible to show this map on raster data structure. An important memory saving can be handled with raster data zipping techniques (Aydan and frd, 2000a).

2.1.5.3. Comparing Vector and Raster Data Models

Vector and raster models have different attitudes and data structures in reshaping geographic data on computer. In order to maintain the sensitivity of positional data in vector data structure, the data in raster data structure should be processed for a long time. In this case, there is a need for great memory capacity to process and record data. While in vector data structure some positional procedures are difficult such as finding common points in two crossing polygons, in raster data these are easy to process but the resulting map is likely to have an unactractive appearance. Both data structure has some advantages and disadvantages. Processing speed and memory capacity which are seen as problem at the beginning are now at the edge of being a problem no more thanks to developing technology of today. With the development of 1024 x 1024 pixels resolution colorful graphic screens, a 300 mm area having a 0,3 mm separating power, can easily be addressed in raster data. Moreover, today these two data structures can be combined and a hybrid geographic data structure is emerging. After all, the advantages and disadvantages of these two data models can be summarized as such (Burrough, 1998);

The advantages of vector data models:

a) Enables direct reflection of real situation into data structure.
b) Has a total data structure.
c) Topologic structure is defined clearly in web connections.
d) Has true graphic display depending on scale.
e) Permits to reach, update and generalize graphic and non-graphic data.

The disadvantages of vector data models:

a) Data structure is complex.
b) Has difficulty in crossing numerous vector and raster shapes with polygon feature.
c) Simulation is difficult as geographic elements are in different topologic formations.
d) Costs a lot to display high quality and colorful images and print.
e) Needs expensive technologic products because multi-sided and sensitive software and hardwares are needed.

The advantages of raster data model:

a) Data structure is so simple.

b) Enables combination of satellite and map images.
c) Realizing different positional analysis is easy.
d) Simulation is easier because the pixels are the same size and shape.
e) Doesn’t cost much thanks to the developments in raster technology.

Disadvantages of raster data models

a) Graphic data need huge size.
b) Although by increasing pixel size data decreases, it results in corruption on display and huge amount of information loss.
c) Raster map drawing is worse than sensitive maps.
d) Difficult to build web or connections between objects.

2.6. Positional Analysis in GIS

GIS enables, as a decision making tool, to analyze graphical and nongraphical information as whole and multi-dimensional (Şen, 2004).

Basic analysis kinds essential in GIS are as such;

1. Spatial query
2. Spatial analysis
3. Network analysis
4. Geometrical analysis
5. Digital terrain analysis
6. Grid analysis
7. Statistical analysis

The basic steps in analyzing in GIS are;

1. The objective is to identify criteria and methods in analysis.
2. Preparing data for positional analysis.
3. Processing positional analysis.
4. Preparing the resulting data for table based evaluation.
5. Processing table analysis.
6. Evaluating results.
7. Improving analysis if it is essential.

2.2. BEARING CAPACITY

2.2.1. Introduction

Standart penetration test (SPT) is the most widely used field experiment in the world. In 19th century, borings were opened with water and the soil type was determined by means of examining boring items put out in boring mud with water in America. Then, in 1902 Cor. Charles R. Gow developed a 1 inch sample collector driven by a 50 kg drop-hammer (Fletcher, 1965). In time, different versions of this sample-collector were done in USA. Standart penetration experiment was used to maintain an opinion about soil and as a sample collector for real defining of Soil by Raymond Boiling Co. In 1920s (Douglas, 1983).

Terzaghi, also stated that besides soil type, SPT could also collect data about the denseness and density of the soil. This recommended sample collection method is almost similar to today's SPT standarts. Terzaghi and Peck (1948), suggested many design and correlation under the light of data obtained data from SPT. Since then, the use of SPT has rapidly increased, especially in America and England, in world.

The experiment equipment is simple and almost every SPT firm has one. The SPT can be described as dropping a 63,5 kg tilt-hammer from a 76,2 cm high until reaching some 45 cm penetration at the bottom of wellbore what is also known as vertical vent and calculating necessary tilt number (SPT-N). The experiment time is short and simple and as it is applied throughout the world there is enough information and database to interpret the results. The sample collected during the experiment enables health description of soil. Thus, in all aoil applications SPT is carried.

Empirical methods have been developed for expecting bearing capacity on surface bases and piled raft foundation especially on cohesionless soil. Thus, the SPT has a specific place in geotechnical designing. The advantages and disadvantages of SPT are given in Table 1. (Kulhawy ve Mayne, 1990).

De Mello suggested at the beginning of 1980s to build "*international Reference Test Procedures, IRTP*" in order to standardize methodology of experiments which was differing all around the world (Clayton vd., 1995). So that internationally valid single type SPT was started by ISSMFE in 1988 (Décourt, 1990). Except for this, there are many standards around the world, and among them English (BS: 1377, Part 9: 1990), American and Japanese ones are the most valid standards (Clayton vd., 1995).

Table 2.1. The Advantages and Disadvantages of SPT (Erol and Çekinmez, 2014).

Advantages	*Disadvantages*
- Test duration is short.	- It is affected by operators mistakes.
- Doing the experiment is simple.	
- It has the largest application time and data. It is the most widely used experiment style in the World.	- Experiment results are highly sensitive and consequential to numerous parameters from boring equipment to application method.
- It is less expensive among experiment whch allows both to calculate penetration power and collect sample.	- the results will not be healthy as the sample collector can easily get harm on big granular, bloc or stone soils.
- Besides cohesion and cohesionless soils, it can also be applied on dense, fine gravel and made soils.	- It can give false results in highly soft and clay soils. - It has possibility of giving false results and cause boiling below soil water level.
- There are many methods in literatüre to maintain enginerring data and parameters from SPT.	

2.2.2. Experiment Equipment and Details

The SPT equipments are generally consisted of;

- Tilt-hammer and dropping equipment
- Stem bars
- Horizontally cut tube sample collector

The equipments can differ from country to country. It is because the equipments indicated above could be different from each other. As a result, the energy transferred will differ and even under similar or same circumstances, same soil under same conditions, the calculated SPT-N values will differ. In this chapter, different types of each unit are given. The effect of different units on experiment results and the adjustment coefficients according to these are given in Chapter 1.4.

Hammer and dropping equipment: When we investigate tilt-hammer dropping equipments in different countries, we find three methods:

a) **Authomatic Dropping Hammers:** The authomatic dropping tilt-hammer shown at figure 3, doesn't let operator mistake, the energy deviation transferred to stem bars are low and thus is the most healthy one. According to Clayton (1990), with authomatic dropping hammers, % 73 of initial energy can be transferred to soil and standard deviation is around % 2,8. Authomatic dropping tilt hammers are used in England standardly and in countries like America, Japan and Israel it is widely used (Clayton, et al., 1990).
b) **Manual Dropping Hammers:** In manual dropping tilt-hammers, the hammer is lifted with a lift to a certain high and released freely. The personal mistake ratio is high in this method and thus is not widely used.
c) **Rope Lifted Hammers:** In rope lifted tilt hammers, as it is shown in Figure 3, the rope passes through the roll and pulled with a hammer. According to ASTM D1586, hammer should be pulled at least 100 rotation per minute. With pulling the rope by operator, the tilt-hammer rises and when it is released the tilt-hammer starts to fall freely. During this, there loss of fraction on roll and hammer. Thus, it is important that the tilt-hammer should be pulled to same height and the rope should be wind on to hammer, otherwise different amount of losses will be observed in each time and the experiment will lose its reliability. Consequently, within this method operator faults affect experiment process. Nevertheless, this rope-pulled tilt-hammers are most widely used in all round the world, especially in USA, Japan and South America. In rope-pulled tilt-hammers, roll type and safe tilt-hammers are used as shown in Figure 4.

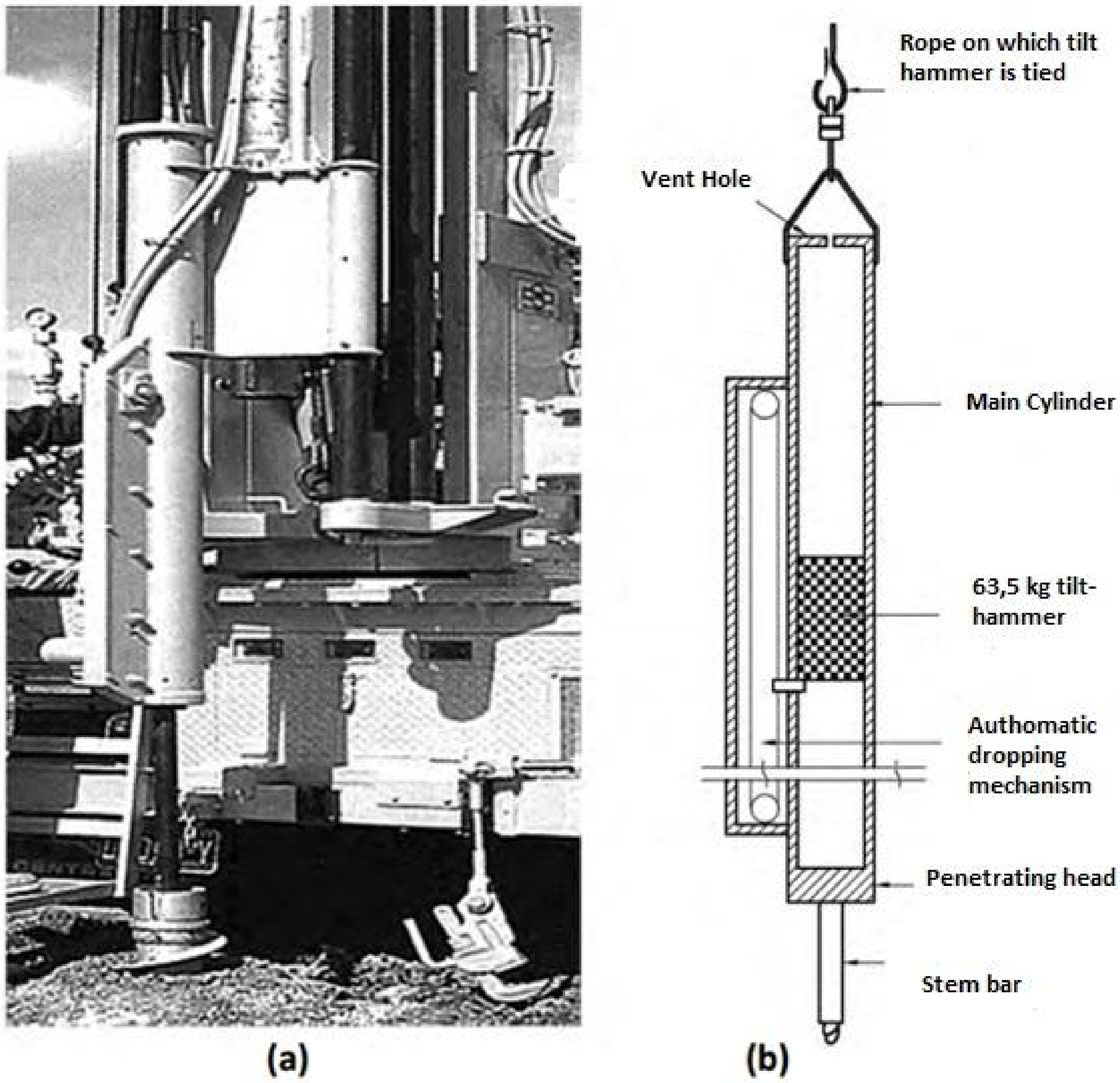


Figure 2.2. Authomatic Falling Hammer Mechanism (a) FHWA (1997) ve (b) Coduto (2000)

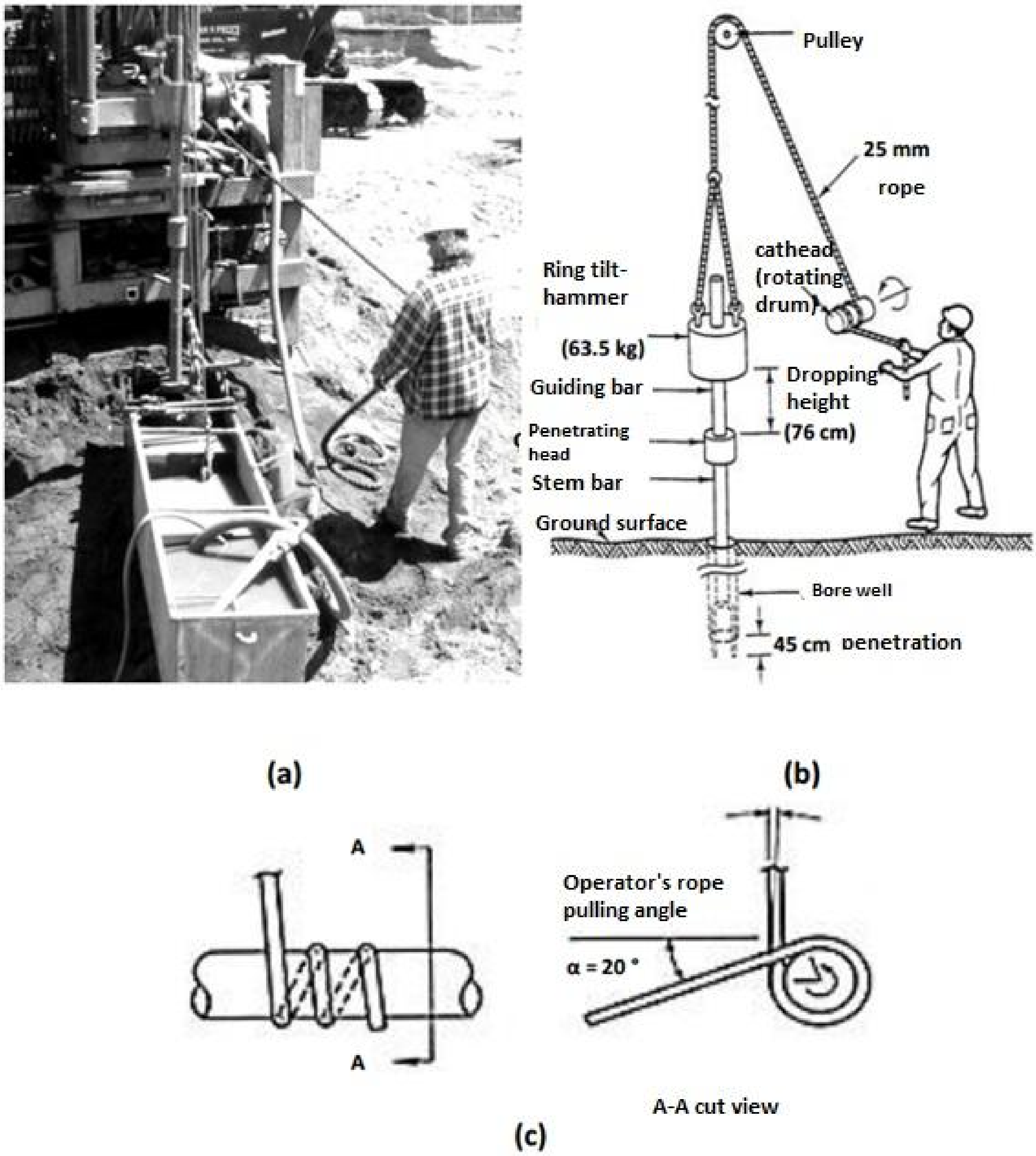


Figure 2.3. (a) and (b) applying rope-pulled system (Coduto,2000), (c) hammer details (the position when it turn aroun 1.81 on counter clockwise, ASTM D1586-11)

Steam Bars: Stem bars are equipments which transfer torcs during wellboring and loss carring capasity in tilt-hammer dropping process. Stem bars are also important figures in energy loss in additional to tilt-hammer type and dropping mechanism. Thus, in English standards there are some conditions for stem bars' having certain weight and rigidness, these are (Clayton vd., 1995).

- In BS 1377, it is stated that stem bars must be made from fine quality steel; up to 20 m depth wells the rigidness of stem bars should be at least AW the one stated in BS 4019 and in the wells deeper than 20 m, this should be BW type.
- In BS 1377, it also stated that stem bars heavier than 10,0 kg/m shouldn't be used, preventing deflection at stem bar connection and finally the relative deviation along the stem bar should be less than 1/1000 of bar length.

the stem bar types, sizes, cut view and weights, suggested by IRTP and BS 1377 , are given in table 1.2.

Figure 5. Some of the tilt-hammer types used in rope-pulling technique (a) roll type tilt-hammer and (b) secure tilt-hammer (Coduto, 2000)

Table 2.2. Stem Bar Qualifications according to IRTP and BS 1377 Standards

Standard	*Type*	*Diameter (mm)*	***Cut View,*** Z_e ***(m³ x 10⁶)***	*Weight (kg/m)*
IRTP	-	40.5	4.28	4.33
	-	50.0	8.59	7.23
	-	60.0	12.95	10.03
BS1377	AW	43.6	5.10	4.57
	BW	54.0	8.34	7.86

Horizontally Cut Tube: the dimensions of tube is given in figure 1.4. In some cases, lined sample collectors are used to prevent tube's falling the sample.

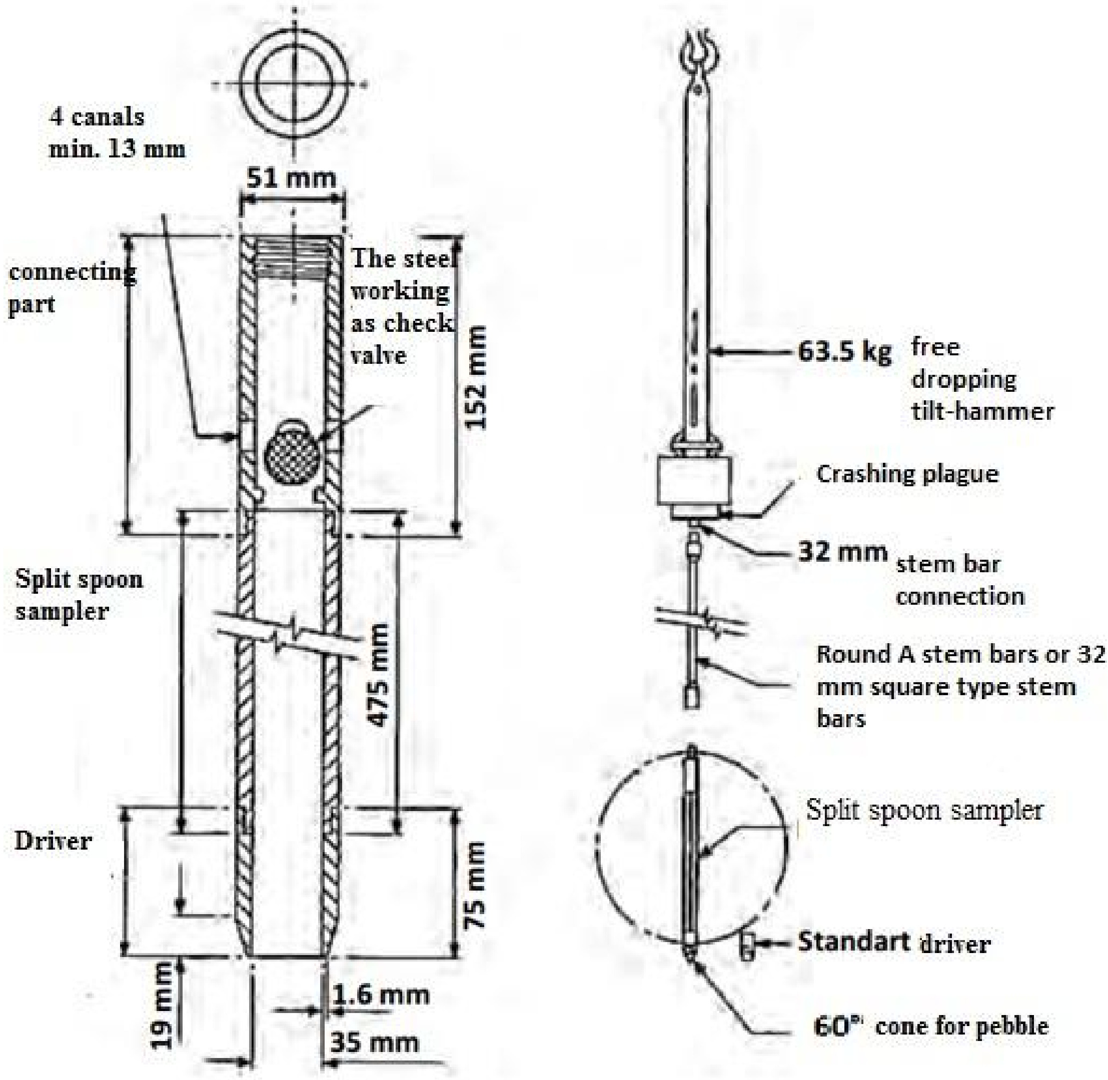


Figure 2.4. The Dimensions of Horizantally Cut Tubes (Clayton vd., 1995)

The sample collected during the experiment is corrupted and generally gorund type and class are identified with this sample.

Sliding Shoe: Generally at the edge of sample collector, a standard open cut base is used. In granular pebbled soils, instead of this base, a 60° holeless conical base is used. Clayton (1993) claimed that conical base increases penetration resistance to double and suggested not to use it. Standard open and holeless base are shown in figure 1.4.

2.2.3. SPT Working Method

The experiment depends on the penetrating a standard sized split spoon sampler with the free fall of 63.5 kg tilt-hammer from 76.2 cm height.

For this experient a borehole drill is necessarry. After cleaning borehole drill, the depth of experiment is recorded with 0,030 m accuracy. After fixing the SPT tube on boring stem bars, the tubes are swinged to the bottom without falling. Then 3, 15 cm, progressing steps are drawn on stem bars. For each 15 cm step, free dropping number of tilt-hammer is calculated. On hard soils, if in one of 15 cm progressing steps, any 15 cm penetration is not reached then the experiment is stopped and it is noted tat refü value is reached. This situation is noted as 50 penetration quantity. In some cases, the experiment is stopped if less than 300 mm is reached at the end of 100 tilts. If any progressing isn't reached at the end of 10 tilts, then the experiment again is stopped.

The first 15 cm is defined as penetration indwelling area and the number of drops here is not considered because of the remolding at the bottom of soil. Then the number of drops for penetration are recorded in the second and third 15 cm as SPT Number, N. The experiment generally is repeated at 1,5 m in wellbore. It is not suggested to apply the experiment for soils where maximum piece size is larger than the diameter of sample collector. The steps of SPT penetration experiment is given in figure 7.

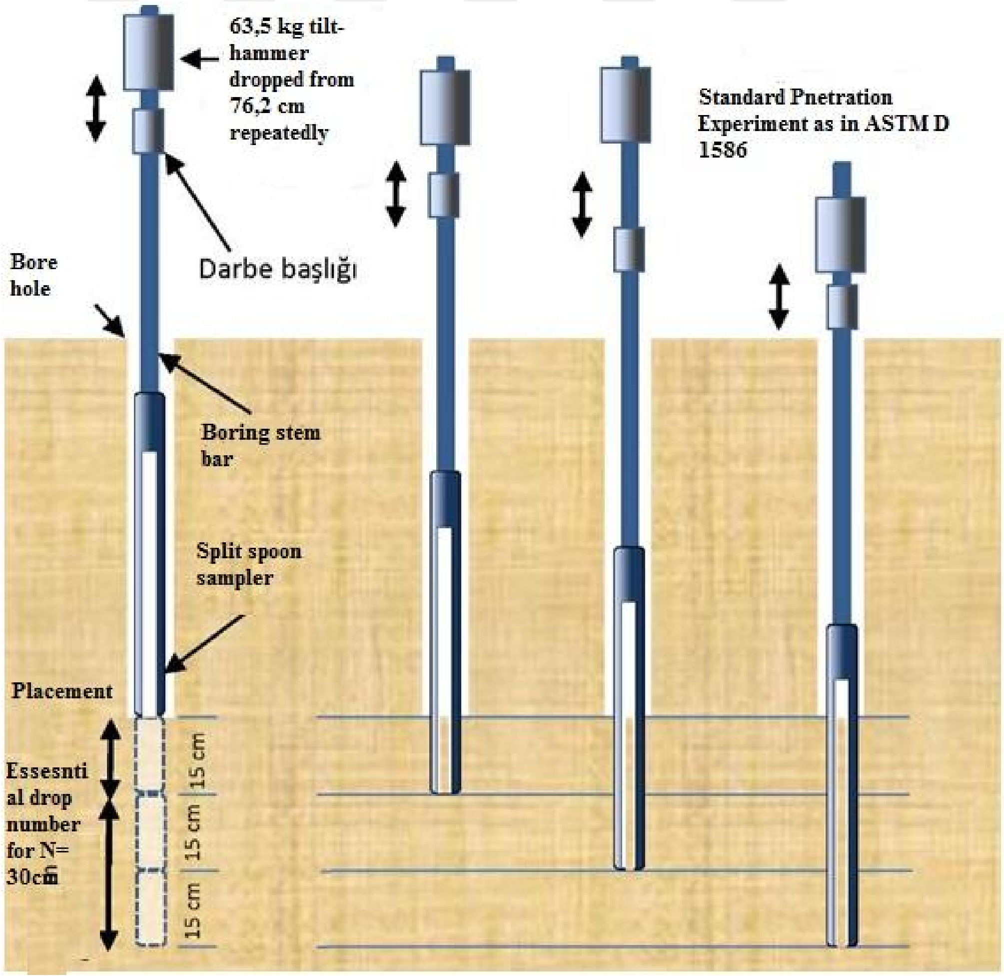


Figure 2.5. Steps of standard penetration experiment (FHWA, 2002b) 1.4. SPT-**N** Factors affecting SPT-N Values and possible mistakes

Generally, during experiment process there some mistakes orginating from operator and not obeying standards. These mistakes can affect experiment results to a large extend. NAVFAC DM-7.1 (1982) calculated the effects of mistakes, being done before and during the experiment, on SPT-N value, it is given in table 1.3.

Tableo 2.3. Factors likely to affect SPT-**N** value (NAVFAC DM 7.1, 1982)

Factors	**Effects on SPT-N value**
Not cleaning wellbore hole	It is possible to take false results as the wellbore mud can mix with original soil. the mud can block sample collector and SPT-N value will increase.
Split spoon sampler’s not standing on soil rightly	SPT-N values are deceptive.
Driving split spoon sampler on regulator cover	SPT-N values increases on sand soil whereas decreases on cohesion soil.
Not reaching enough hydrostatic level in wellbore	the level of soil water and piyezometrik level of wellbore in sand soil should be the same. Otherwise, the sand at the bottom will loose and finally SPT-N value is lower.
The attention of operator	Operator should apply each step of the experiment same and right. The training level of operator, level of seriousness and environmental and weather conditions can affect results.
Blocking of sample collector on granular soil	SPT-N values are higher than expected.
Blocking of regulator cover	Hidrostatic pressure will arise sand into pipe and block it. SPT-N can increase under loose sand below water.
Over washing in front of regulator cover	It decreases SPT-N values on dense sand soil.

Factors	Effects on SPT-N value
Not realizing tilt hammer's free drop	In case when the rope roll around turning drum more than 1,5 times, free dropping is prevented. Calculated SPT-N values are higher than expected.
Tilt hammer's crashing on drivehead eccentricly	Because the crash power decreases calculated SPT-N values are higher than expected.
Not using Pioneer stem bar	Calculated SPT-N values are deceptive

2.2.4. Corrections for SPT-N

As it is stated before the changes in experiment mechanism can affect SPT-N values. Moreover, the pressure of water rising during the penetration on silty sand and fine sand soils changes drop number. Thus, before a number of corrections are need to be converted to SPT-N before interpreting experiment results. These corrections are explained below:

Silty sand – fine sand Correction: This correction is also named as dilatancy in some sources. Water depending on dynamic rises can not be drained because of the low permeability on silty or fine soils. The existance of undrained water increases soil durability temporarily and thus increases SPT-N value fallaciously. So that if all the conditions below are valid then silty sand correction is done;

i. If the experiment is done below the oil water level
ii. If the soil is silty or fine sand
iii. If N>15 drop/30 cm

Silty sand correction is done by means of this formula (Terzaghi and Peck, 1948), (Sekercioglu, 2002).

$$N' = 15 + \frac{1}{2}(N - 15) \qquad (1.1)$$

Energy Correction: the dynamic energy applied to SPT tube is dropping a 63,5 kg mass from a 76,2 cm height as standardized per beat. Furthermore, the energy transferred to the edge of tube can decrease to % 40 (473,4 jül). The main causes of energy loss are as such (Clayton et al, 1995):Ihe energy damped by stem bars and tilt-hammers

- Heat and sound energy emerged as a result of tilt-hammer's crashing on stithy
- Inclining of stem bars or use of small moment of inertia stem bars
- Energy loss on soil where ropes scrape between different parts of tilt-hammer.

The experiments showed that energy levels, being transferred from experiment mechanism to the soil are changing depending on tilt-hammer and dropping mechanism. Finally an energy correction is envisaged on SPT values. In energy corrections, % 60 energy transfer obtainable in secure tilt hammer system is taken as standard and propotioned to energy transfer rates in other sytems. There are energy values used in different countries for different systems are given in table 1.4.

Although secure tilt-hammers are started to be used in our country, generally role type tilt hammers, hammer and double roling systems are broadly used. As it can be seen in table 1.4. The energy ratio is around % 45 in these systems. When table 1.4. is investigated, it can be understood that the energy ratio changes from % 43 to % 85, and thus without doing energy correction SPT value can change two times.

The drop number to maintain enough penetration on soil and the energy transferred to SPT tube are inversely proportional, the formula 1.2. between these two energy transferring system is given below (Clayton vd., 1995).

$$\frac{N_x}{N_y} = \frac{E_y}{E_x}$$

So that if average energy ratio for tilt hammer and dropping mechanism is E_y, and SPT-VV recorded in field is N_y, the energy ratio value N_x is given in formula 1.3.

$$N_x = N_y * \left(\frac{E_y}{E_x}\right) = N_y * C_E$$

Here C_E is the energy ratios for two systems taken from table 1.4.

Table 2.4. Energy ratios depending on hammers and dropping mechanisms (Clayton vd., 1995)

Country	**Tilt hammer type**	***Tilt hammer* dropping mechanism**	**Energy Ratio (%)**
Argentina	Ring	Hammer	45
Brasil	Spiny weight	Hand releasing	72
China	Automatic ring	Hand releasing	60
	Ring	Free releasing	55
	Ring	Hammer	50

Colombia	Ring	Hammer	50
Japan	Ring	Tombi	78 - 85
	Ring	Hammer, 2cycle	65, 67
England	Automatic	Gitgel	73
USA	Secure	Hammer, 2 cycle	55 - 60
	Ring	Hammer, 2 cycle	45
Venezuela	Ring	Hammer	43

a) Corrections for drill caliber, tube type, stem bar length, drop speed: Corrections are applied to SPT-N values according to drill caliber, the existance of lining in standard penetration tube, drop speed adn stem bar length in experiment, these corrections suggested by different researchers are given in table 1.5.

b) Overburden correction: On the condition that soil is homogenus and has unit weight and water content not depending on deepness, SPT-N values increase with deepness. This is because the overburden stress increasess when we go deeper as the experiment is applied in higher vertical and horizantal environmental pressure. Consequently, drop number also increases to reach same penetration. SPT-N values, of which overburden correction is done, are shown as N_1 .

c) In order to describe same qualified soils free from deepness with a standard penetration N value, overburden effect C_N correction is used. In the definition of this factor in deepth where effective overburden value is (σ'_{vo}) is approximately 100 kN/m^2 ; $C_N = 1.0$, in lower overburden $C_N > 1.0$ and in higher overburden $C_N < 1.0$ are taken.

Overburden correction should not be applied on cohesion soils as soil is drainless during the experiment.

There are many suggested methods for overburden correction factors. The comparing table for Bazaraa (1967), Seed (1979) and Liao & Whitman (1986)'s formulas are given in figure 1.6. The overburden correction factor values ranges between 0,5 and 2,0. Canadian Design Manual (1994) suggested to take 1,5 value as maximum without concrete reasons.

2.3. LIQUEFACTION

2.3.1. Introduction

The term, liquefaction; first used by Japan researchers Mogami and Kubo in 1953, has been used widely in terms of identifying all the conditions under which water could not escape from soil, and cohesion soils once, permanently or repeatedly collapsing because of the water (Ulusay, 2000). Generally in geologically young and alluvial sediments, sandy, silty sandy where sediments are reserved and soil water is around 10 m is stated as liquefaction area.

2.3.2. Liquefaction and Soil Failures

2.3.2.1. Loss of Bearing Capacity

The soil, lose it strength with liquefaction, can not carry the burden of the building on it and consequently the buildings started to slant and tumble down. In 1964 Niigata (Japan) earthquake 7,3 on the richter scale, buildings were observed to slant (figure 4.1 and 4.2.) and after this earthquake researchers started to study liquefaction phenomenon and it still is going on. Besides collapse of heavy buildings, liquefaction also affects pipes, tanks and etc.

Figure 2.6. 1964 Buildings slanting and tumbling down by means of liquefaction in Niigata earthquake (Steinbrugge Collection, Earthquake Engineering Research Center, University of California, Berkeley) (Şen, 2004).

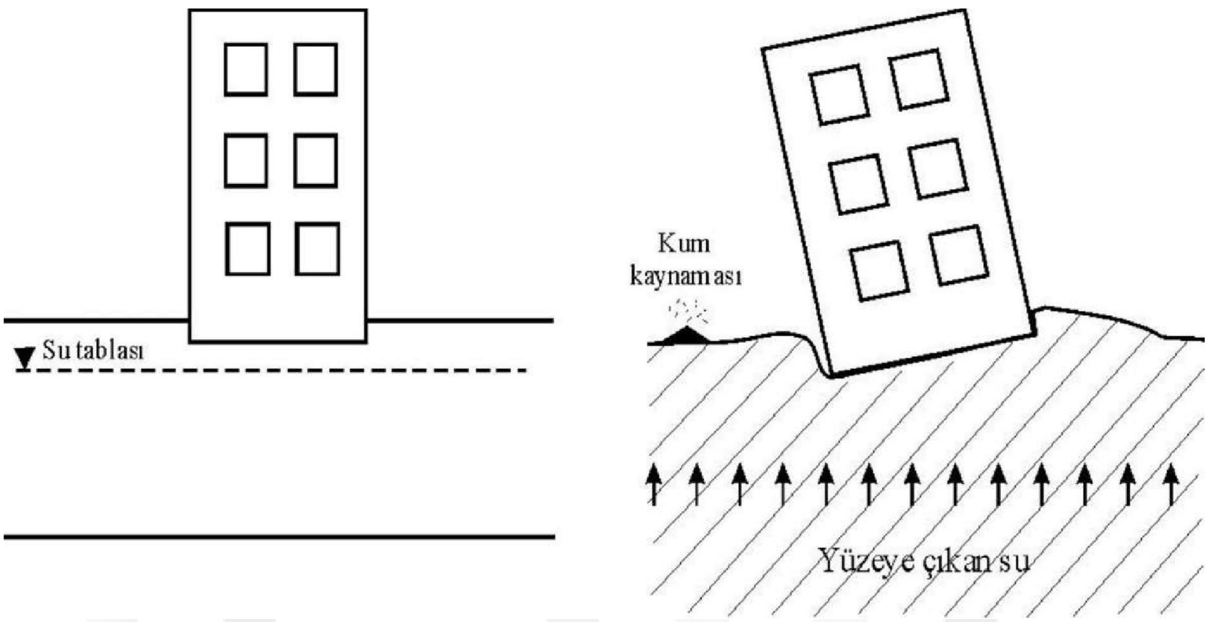


Figure 2.7. Soil's Loss of carring capasity and building slanting (Ulusay, 2001).

Figure 2.8. Loss of bearing Capacity (17th August 1999 Kocaeli-İzmit Earthquake) (Şen, 2004).

4.2.2. Sinking of Soil

During liquefaction, with the attitudes of granules becoming together and leaving, and buildings on are likely to slant, in 1999 Kocaeli earthquake damages in Yalova and Adapazarı were seen. Broad spread liquefaction appeared along the 120 m faultline (Aydan et al, 2000b).

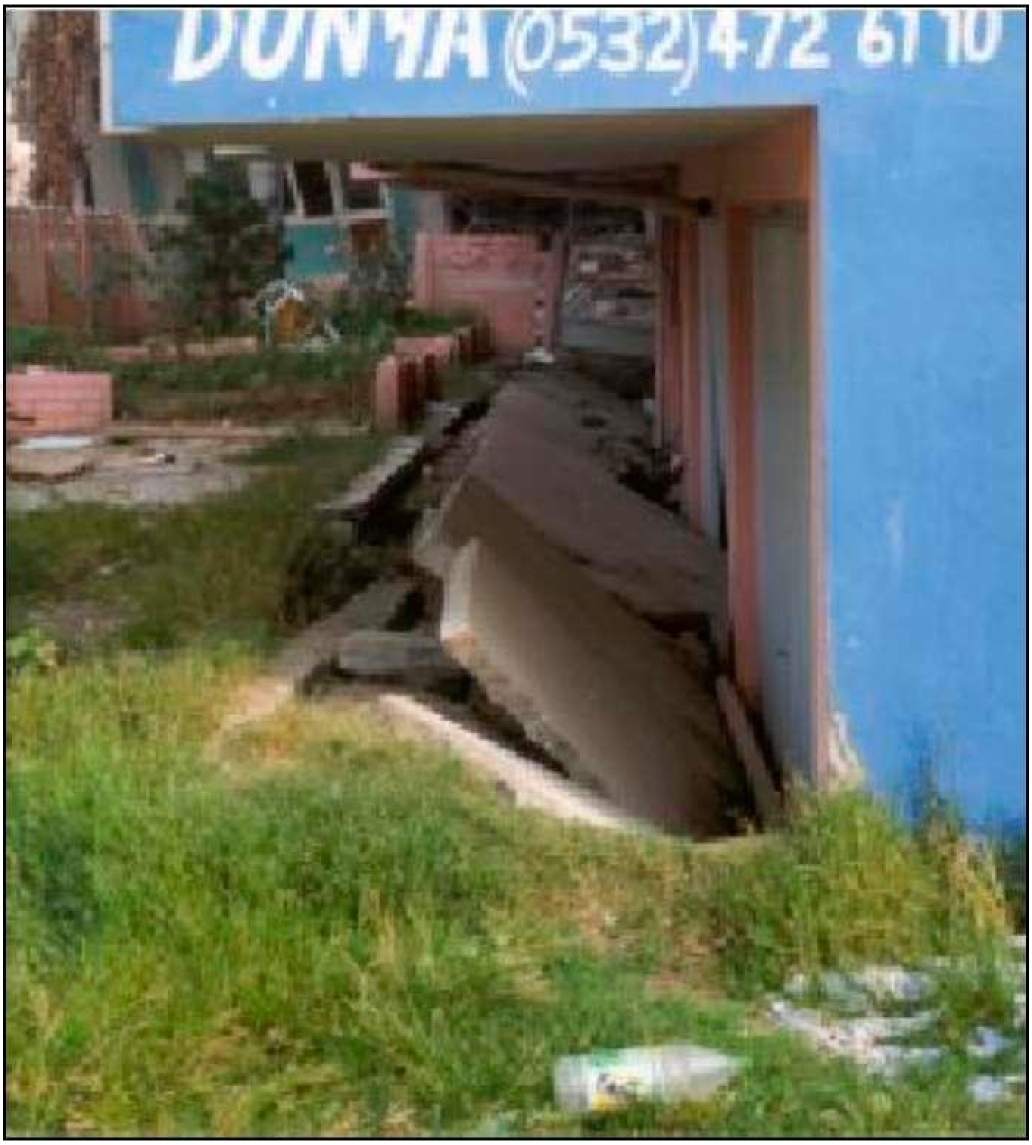


Figure 2.9. Sank Buildings in Adapazarı in 1999 Kocaeli Earthquake (Şen, 2004).

2.3.2.3. Lateral Spreading

Lateral spreading can be described as dividing large blocks of Soil levels above liquefaction Soil and moving of these blocks. Lateral spreading occurs on to free Soil areas such as river, lake and sea coast and areas with % 3 – 5 inclination. As a result of movement there are fissures, faults, small sediments and elevations on surface.

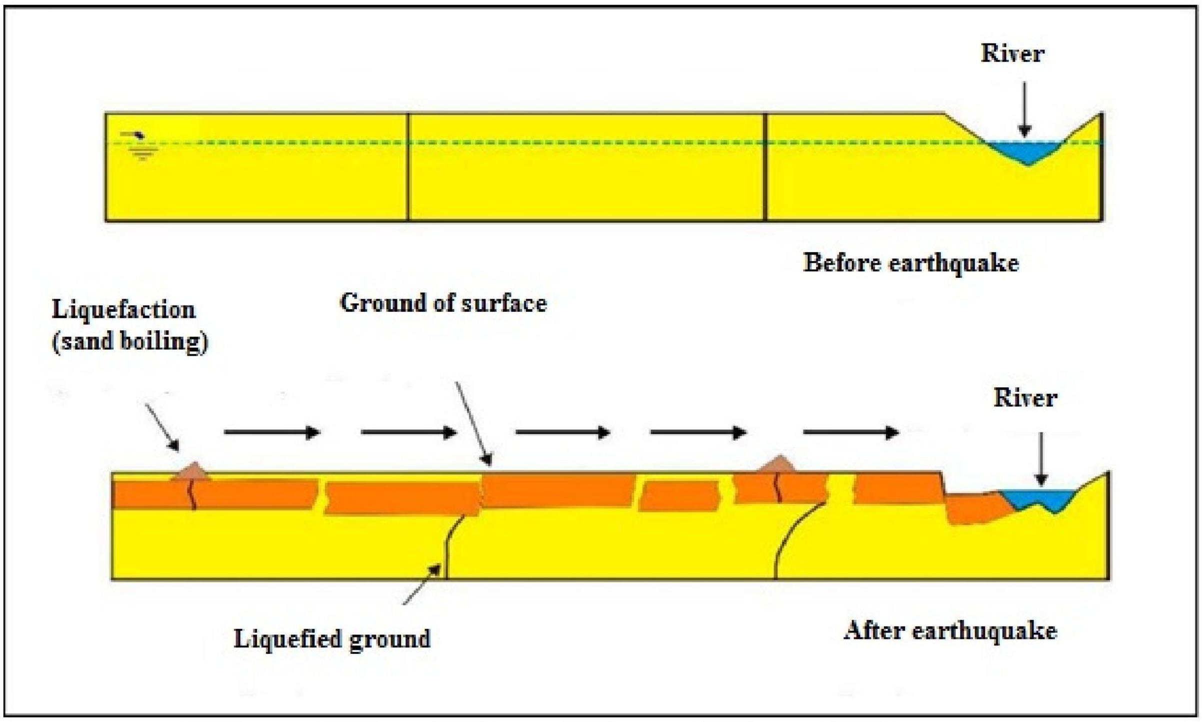


Figure 2.10. Development of Lateral Spreading (adapted from Obermeier, 1996).

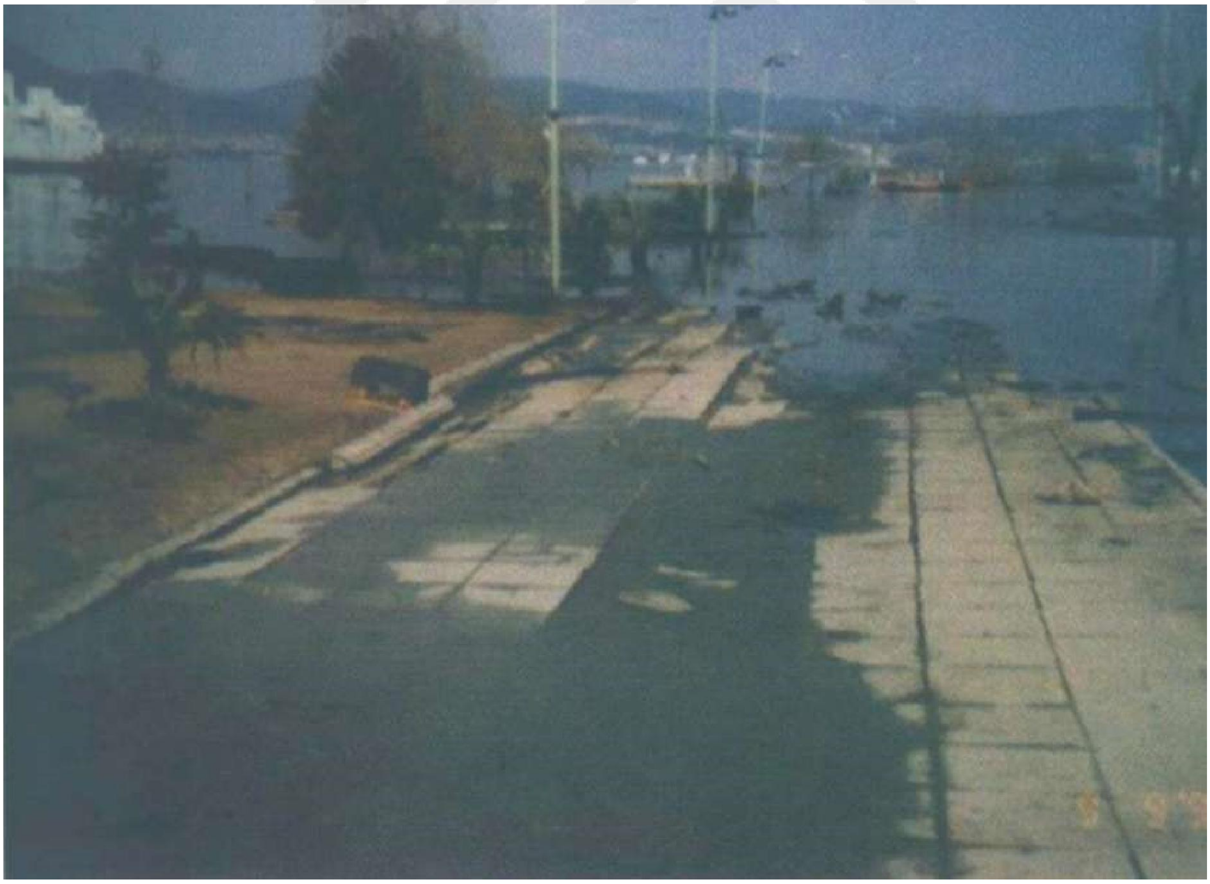


Figure 2.11. 1999 Beach Road slided into sea with lateral spreading in Kocaeli earthquake, (Ulusay, 2000).

In our country, as in many earthquakes, liquefaction occured along the Ceyhan river during the earthquake took place in 1998 in Adana-Ceyhan 6.3 on richter scale (Ulusay et al, 2000). Liquefactioned level could not reach on surface on every ocaasion. This condition depends on the width of liquefactioned level, the existance of another level on liquefactioned level and width of it (figure 4.7). In Ceyhan, with the emerging of liquescent sand on surface, sand volcanes occured (figure 4.8 and 4.9). Liquefaction draw many's attention with the damages of Kocaeli – Bolu-Düzce earthquakes. Also in 3rd February 2003 in Çay-Eber earthquake 6.0 on Richter scale, liquefaction was seen in 1-1,5 m from surface and in some places it couldn't be seen which was described with clay and silty levels existance (Ulusay et al., 2002).

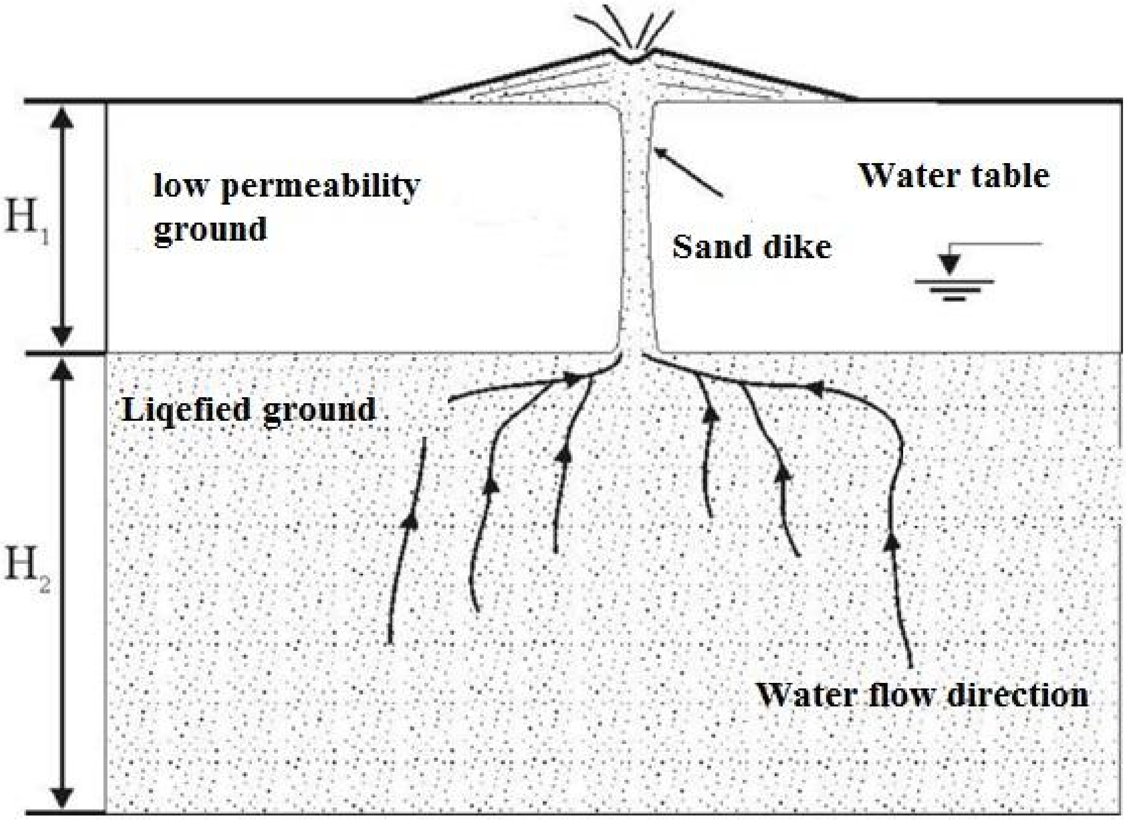


Figure 2.12. Sand's moving to surface with liquefaction (adapted from Obermeier, 1996).

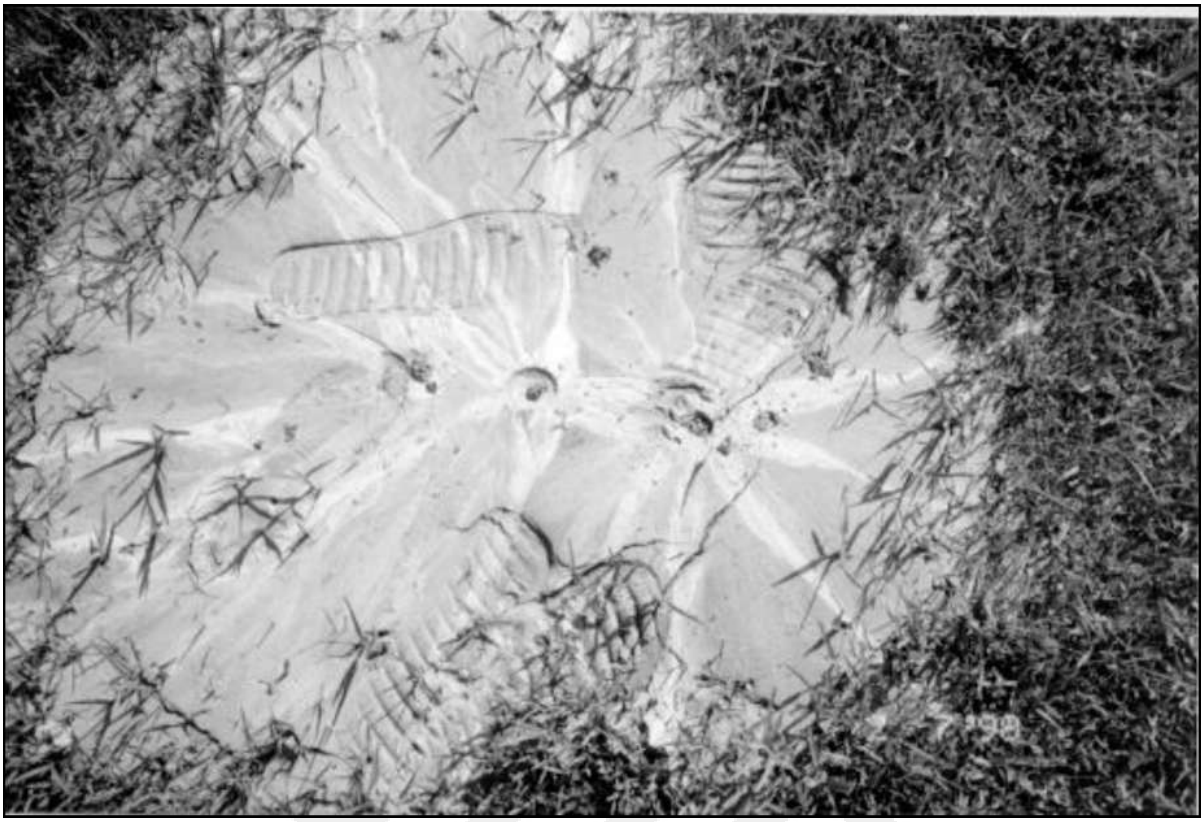


Figure 2.13. Sand volcanes in 1998 Adana-Ceyhan earthquake (Photo: Halil Kumsar).

Figure 2.14. Soil liquefaction and sand boiling on right shore of Ceyhan River as a result of 1998 Adana-Ceyhan earthquake (Şen, 2004).

2.3.2.4 Sliding liquefaction

Sliding liquefaction occurs on surfaces where the slope is bigger than % 5. During sliding, huge levels of soil can easily move tens of kilometers in short. Sliding can occur on fully liquefactioned soil or with hard levels on it (figure 4.10 and 4.11).

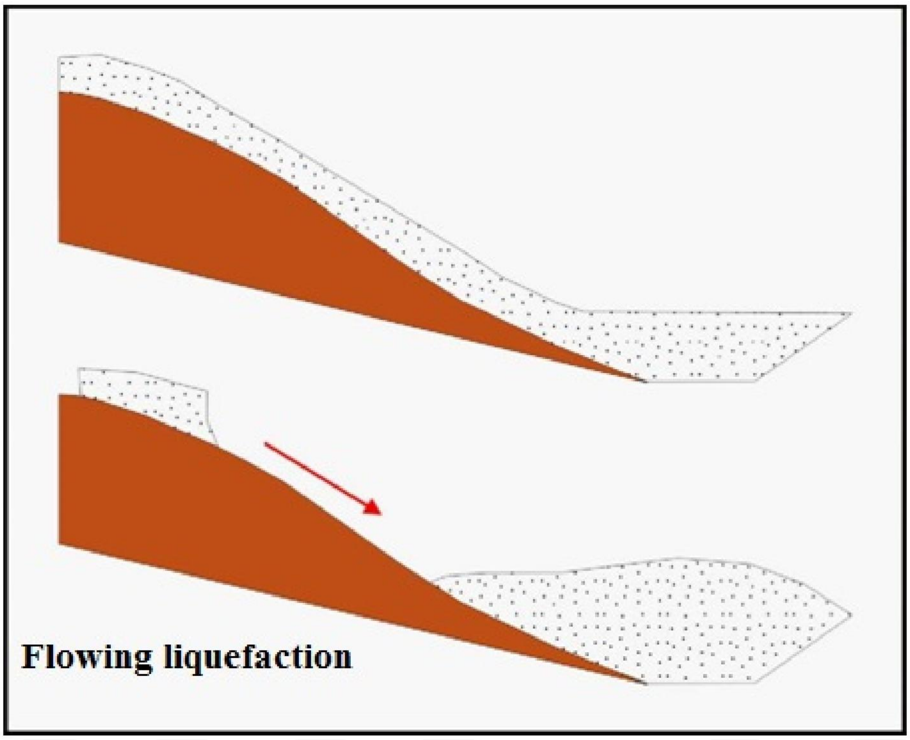


Figure 2.15. Sliding of loose material on inclined surface with liquefaction (Çelik,2003).

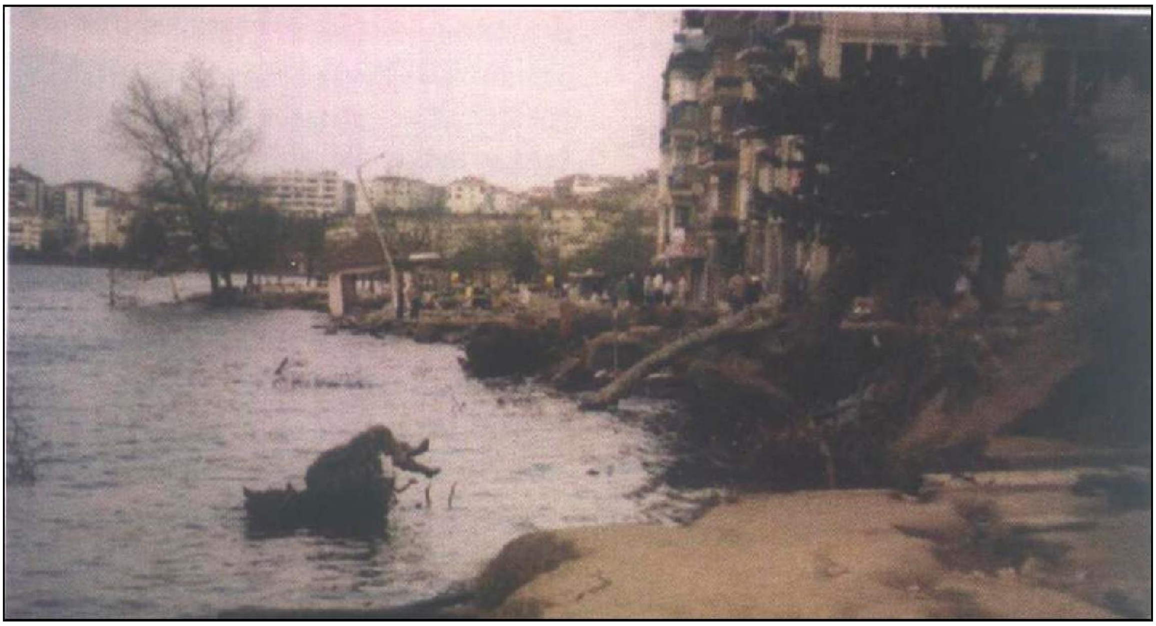


Figure 2.16. Sliding liquefaction occured in Değirmendere towards sea during 1999 Kocaeli earthquake (Ulusay, 2000).

2.4. SHEAR WAVE VELOCITY

The standart penetration test is by far the oldest and the most commonly used in situ test in geotechnical engineering. In the SPT, a standart split barrel sampler is driven into the soil at the bottom of a borehole by repeated blows (30 to 40 blows per minute) of a 63.6 kg hammer released from a height of 76 cm. The sampler is usually driven 46 cm. The number of blows required to achieve the last 30 cm of penetration is taken as the standart penetration resistance, N. The N value is a function of the soil type, confining pressure, and soil density, but is also influenced by the test equipment and procedures.

In recent years, the S wave velocity and SPT (Standard Penetration Test) data has gained considerable importance to determine liquefaction safety factors.

The shear wave velocity playing an important role in the dynamic behavior of soils is determined by measuring in-situ or calculating converted depending on other rigidity parameters such as SPT-N numbers, CPT (Cone Penetration Test). In-situ measurement of shear wave velocity with a borehole tapped in the field is carried out with downhole seismic experiments used in geotechnic.

However, the in-situ measurement of shear wave velocity has disadvantage in terms of economy and time for the study. The equations have been developed that shear wave velocity calculates with the direction of penetration test to eliminate this nuisance. Therefore, in practice shear wave velocity calculated with SPT-N numbers mostly.

In this thesis, 287 boreholes made in the study area are used. These logs, SPT's are examined that they are made starting from first 1.5m up to 30 m depth and N values are obtained from them. For the relationship between SPT-N and Vs velocity, shear wave velocities were obtained through the use of empirical equations developed by various researchers.

CHAPTER 3

3. ANALYSIS OF CALCULATIONS

3.1. Bearing Capacity Calculations

Bearing Capacity Theory

The stability of foundations depends on the bearing capacity and the settlement of the soil beneath the foundation. Bearing capacity is defined as the maximum average contact pressure between the structure and the soil which should not produce shearfailure in soil. In simpler terms, bearing capacity is the capacity of soil to support the loads applied to the Soil. So, the shearing resistance of the soil provides the bearing capacity and the consolidation properties determine the settlement and these two conditions together determine the stability of the foundation.

There are various bearing capacity definitions that relate to different design considerations. For example, for the sake of practicality, the two independent criteria of shear failure and settlement problem have been molded into a single parameter called the allowable bearing capacity (qall). It is the maximum permissible pressure that can be applied to the soil without creating neither shear failure nor excessive settlements. On the other hand, the ultimate bearing capacity (qu or qf) is the theoretical maximum pressure which can be supported without shear failure of the soil. Clearly, allowable bearing capacity inherently includes a factor of safety whereas ultimate bearing capacity does not. Therefore, this research focuses on the ultimate bearing capacity and accordingly the underlying mechanisms of bearing capacity problem will be discussed. Here, some of the well-known ultimate bearing capacity determination methods will be introduced.

In 1943 Terzaghi presented a solution to the bearing capacity problem that was based on the Prandtl solution. However Terzaghi modified the solution to account for the deficiencies inherent in the Prandtl's assumptions as applied to the soils. Prandtl equation is improved by adding an additional term to take into account the component of the bearing capacity due to self weight of the soil. Terzaghi, also assumed that the friction acts along the interface between the soil and the footing.

BH NO	SAMPLE NO	N15	N30	N45	SPT N	ADJUSTED SPT N	BEARİNG CAPACITY (kg/cm2)
150	1	18	20	14	34	24,5	4,3
150	2	16	22	19	41	28	5
150	3	17	20	21	41	28	5
150	4	24	20	28	48	31,5	5,7
150	5	30	27	30	57	36	6,6
150	6	26	21	26	47	31	5,6
150	7	30	24	28	52	33,5	6,1
150	8	50	50	50	100	57,5	10,9
150	9	50	50	50	100	57,5	10,9
150	10	50	50	50	100	57,5	10,9
196	1	7	11	10	21	18	3
196	2	9	13	12	25	20	3,4
196	3	11	14	16	30	22,5	3,9
196	4	14	12	18	30	22,5	3,9
196	5	9	15	19	34	24,5	4,3
196	6	16	18	21	39	27	4,8
196	7	13	20	19	39	27	4,8
196	8	18	24	27	51	33	6
196	9	15	27	33	60	37,5	6,9
96	10	17	34	32	66	40,5	7,5

Bearing capacity formula (Sekercioglu, 2002)**;**

q_d=(N'-3)/5 (kg/cm^2) **(1.1.1)**

where N' is corrected SPT-N value.

3.2. Liquefactıon Analysis

There are many analysis methods in literatüre depending on field and labarotary experiments in order to determine liquefaction sensitivity. Because of the fact that labaratory experiments take long time, and they are expensive and undamaged sample collecting, in searching liquefaction potential field studies are preferred. of these, SPT and CPT are most widely used ones but BPT and V_s are also used (Erol and Çekinmaz, 2014).

In this thesis study, SPT strike numbers from field studies are used to determine liquefaction potential of research area. There are 21 wellbores with SPT data in research area. Up to now, the most known methods for liquefaction analysis depending on SPT strike numbers are Tokimatsu & Yoshimi (1983) and Seed & DeAlba (1986). Besides these two methods, in 1996 and 1998, in order to determine soils' liquefaction potential, to maintain a standard method, 20 experts with Leslie Youd and I. M. Idriss leadership came together under NCEER (National Center for Earthquake Engineering Research). With these meetings, previous standards were rewieved and with necessary additions "Youd et al., 2001" was published.

Determining liquefaction is based on calculating safety coefficient against liquefaction of soil. Safety coefficient is calculated by dividing CRR with CSR (Youd et al., 2001).

CSR during earthquake is calculated with the formula 4.1;

$\frac{\tau_{av}}{\sigma'_{v0}}$ (CSR): Repeating stress ratio created by earthquake

a_{maks}: Greatest Soil acceleration (cm/sn^2).

g: Gravity acceleration (cm/sn^2).

σ_{v0} : Total cover stress (kPa)

σ'_{v0} : Effective cover stress (kPa)

r_d : Reducing stress factor

r_d , is a deepth based changing factor (z), the formula is calculated with 4.2. up to 9.15 m. deepthness, while the formula is calculated with 4.3. In deepthness between 9.15 m. And 23 m.

$$z \leq 9.15\, m\ için\ r_d = 1.0 - 0.00765z \quad (4.2)$$

$$9.15 < z \leq 23\, m\ için\ r_d = 1.174 - 0.00267z \quad (4.3)$$

As it is stated in previous chapters, in calcuating soil's resistance ratio against liquefaction (CRR), SPT strike numbers are used. The strike number obtained from SPT experiment (N), as it is known, are processed in a series of corrections and corrected SPT strike numbers ($(N_1)_{60}$) are calculated. These corrections are; overburden correction (C_N), stem bar energy ratio correction (C_E), well diameter correction (C_B), stem bar length used during experiment correction (C_R) and inner tube correction (C_S). The correction coefficients of SPT suggested by Youd et al, (2001) are given in chart 4.1.

For overburden correction (C_N), formula (4.4) is used suggested by Youd et al, (2001).

$$\mathbf{C_N = 2.\frac{2}{1.2 + \frac{\sigma'_{v0}}{P_a}}} \quad (4.4)$$

Here,

$\mathbf{P_a}$: Atmospheric pressure (100 kPa).

$\sigma'_{\mathbf{v0}}$: Effective cover stress (kPa).

The energy ratio of Donut type tilt hammer being used in Turkey is (E_r) % 45. The stem bar energy ratio correction (C_E) is calculated with the formula 4.5.

In every level, SPT experiment is done, in order to calculate corrected strike numbers ($(N_1)_{60}$) this formula is used.

$$(N_1)_{60} = N.C_N.C_E.C_B.C_C.C_R \quad (4.6)$$

Table 3.1. Coefficients to Improve SPT Strike Numbers (Youd et al., 2001).

Coefficient		
Well diameter (C_B)	65-115 mm	1.0
	150 mm	1.05
	200 mm	1.15
Length of Stem bar (C_R)	< 3 m	0.75
	3-4 m	0.8
	4-6 m	0.85
	6-10 m	0.95
	10-30 m	1.0
Use of inner Tube (C_S)	Standard sample collector	1.0
	On occasions inner Tube not used	1.1-1.3

Youd et al., (2001), stated that CRR increases with the rise of fine pieces (<0.075mm) according to liquefaction analysis based on SPT, and suggested a new correction for SPT strike values ($(N_1)_{60}$) and fine piece ratio (FPR) included by soil ($(N_1)_{60cs}$).

α **and** $\boldsymbol{\beta}$ are coeffcients calculated with the formula below.

$$\mathbf{FPR \leq \%5 \text{ if } \alpha = 0, \beta = 1.0} \quad (4.7.a)$$

This equation, is maintaned by drawing a graphic with the data of repeated soil stress emerged during 7.5 earthquakes of different locations (America, Japan and China) (CSR) and

$(N_1)_{60}$, fine piece ratio is between ≤ % 5, % 15 and % 35. SPT is also known as clear sand curve and it is used when fine piece ratio is ≤ 5 in CRR curve calculations (Figure 4.11).

$CRR_{7.5}$ values calculated for 7,5 scale earthquake should be corrected for envisaged earthquakes' scales. For this correction, massive scaling factor (MSF) revised by Youd et al., (2001) is suggested (4.9).

$$FS = \left(\frac{CRR}{CSR}\right) \tag{4.9}$$

Calculated FS values are evaluated according to these intervals:

FS ≤ 1 Liquefaction

FS ≥ 1 No liquefaction

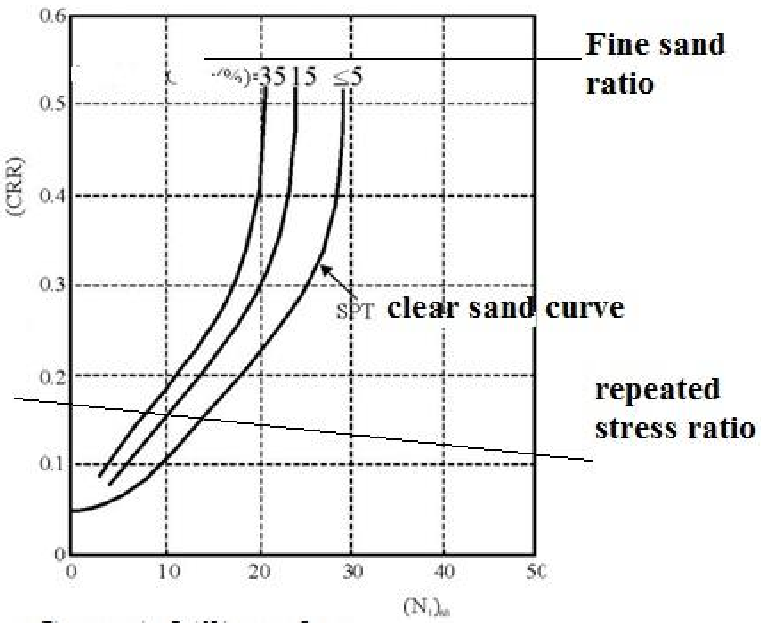


Figure 3.1. The Relation Between SPT Strike Numbers and Liquefaction Data from 7,5 Earthquake of Different Points in the World (Youd et al., 2001).

Besides evaluating soil's liquefaction sensitivity with secure coefficients, liquefaction potential can also be stated with different degrees from low to high together with liquefaction potential index (LPI) suggested by Iwasaki et al., (1978). Liquefaction potential index was developed by Iwasaki et al., (1978) in order to find whether liquefaction cn damage the basement or not. The researchers investigated some 85 scenes from 6 earthquakes in Japan and used SPT and so found that in 63 of them there was liquefaction while in the resting 22 there wasn't.

N1	G (m/sn2)	Cr	Cs	Cb	Ce	Amax (m/sn2)	rd	σv	σv'	N1,60	CSRmaks
46,8305	9,81	1	1	1	0,75	0,26	0,9775	27,369	35,2179	35,12293	0,20134
37,84481	9,81	1	1	1	0,75	0,26	0,955	54,739	47,8728	28,38369	0,28941
30,90016	9,81	1	1	1	0,75	0,26	0,9325	82,1097	60,5277	23,17516	0,33526
30,10536	9,81	1	1	1	0,75	0,26	0,91	109,479	73,1826	22,57902	0,36080
30,77378	9,81	1	1	1	0,75	0,26	0,8875	136,845	85,8375	23,08033	0,37500
24,19075	9,81	1	1	1	0,75	0,26	0,865	164,214	98,4924	18,14306	0,38224
24,20244	9,81	1	1	1	0,75	0,26	0,8425	191,583	111,1473	18,15184	0,38489
38,85851	9,81	1	1	1	0,75	0,26	0,82	218,952	123,8022	29,14388	0,38437
36,63616	9,81	1	1	1	0,75	0,26	0,7975	246,321	136,4571	27,47712	0,38155
34,75611	9,81	1	1	1	0,75	0,26	0,775	273,699	149,112	26,06708	0,37702
33,18007	9,81	1	1	1	0,75	0,26	0,9775	29,43	114,777	24,88505	0,06642
26,06877	9,81	1	1	1	0,75	0,26	0,955	58,86	129,492	19,55154	0,11504
23,94565	9,81	1	1	1	0,75	0,26	0,9325	88,29	144,207	17,95924	0,15131
0	9,81	1	1	1	0,75	0,26	0,91	0	0	0	0
0	9,81	1	1	1	0,75	0,26	0,8875	0	0	0	0
0	9,81	1	1	1	0,75	0,26	0,865	0	0	0	0
0	9,81	1	1	1	0,75	0,26	0,8425	0	0	0	0
21,50670	9,81	1	1	1	0,75	0,26	0,82	235,44	217,782	16,13002	0,23495
23,04172	9,81	1	1	1	0,75	0,26	0,7975	264,87	232,497	17,28128	0,24079
23,60802	9,81	1	1	1	0,75	0,26	0,775	294,3	247,212	17,70602	0,24452

5,00	15,00	35,00	GRAPHICAL RESULTS	FL	LIQUEFACTION RISK PERCENT	FRONT LIQUEFACTION POTENTIAL
18,819309	14,09094	11,51564	14,09094	0,401189	0	1
25,045381	19,41045	16,27284	19,410425	0,683862	0	1
27,307823	21,5004	18,11374	21,50042	0,927739	0	1
28,277282	22,46268	18,94989	22,46268033	0,994847	0	1
28,726409	22,93543	19,35655	22,93545003	0,993768	0	1
28,930617	23,15928	19,54774	23,15923808	1,276477	100	1
29,001285	23,23831	19,61508	23,23836741	1,280221	100	1
28,987455	23,22286	19,60181	23,22281476	0,796838	0	1
28,911793	23,13831	19,52989	23,13832911	0,84209	0	1
28,784937	22,99899	19,41082	22,99892159	0,88229	0	1
4,4869065	2,614689	1,113152	2,614688279	0,105077	0	1
10,320945	7,214717	5,296586	7,214757517	0,369012	0	1
14,181699	10,30573	8,098046	10,30521273	0,573891	0	1
-4,7022	-4,5157	-5,394	-4,7022	0	0	0
-4,7022	-4,5157	-5,394	-4,7022	0	0	0
-4,7022	-4,5157	-5,394	-4,7022	0	0	0
-4,7022	-4,5157	-5,394	-4,7022	0	0	0
21,487757	16,32381	13,52053	16,32341481	1,011941	100	1
21,91427	16,68672	13,84543	16,68620772	0,965567	0	1
22,181206	16,9132	14,0498	16,9137482	0,955259	0	1

3.3. Shear Wave Velocıty Calculations

The in-situ measurement of shear wave velocity has disadvantage in terms of economy and time for the study. The equations have been developed that shear wave velocity calculates with the direction of penetration test to eliminate this nuisance. Therefore, in practice shear wave velocity calculated with SPT-N numbers mostly.

287 boreholes made in the study area are used. These logs, SPT's are examined that they are made starting from first 1.5m up to 15 m depth and N values are obtained from them.

It is used Ohsaki and Iwasaki (1973), Ohta and Goto (1978), Iyisan (1996), Hasançebi and Ulusoy (2007) and Akın et al. (2011)'s equations applied to all soils within the scope of this thesis . These correlations were given in Table 6.

Tablo 3.2. Summary of empirical correlation based on SPT-N and V_s

Researcher	**V_s (m/s) (All soils)**
Ohsaki and Iwasaki (1973)[40]	Vs= 81.4*N^0.39
Ohta and Goto (1978) [41]	Vs=85.35*N^0.348
Iyisan (1996) [42]	Vs=51.5*N^0.516
Hasançebi and Ulusoy (2007) [43]	Vs=90*N^0.309
Akın et al. (2011) [44]	Vs=59.44*N^0.109*z*0.426

HEIGHT OF FALL	TYPE OF SAMPLE	DEPTH	REMAINING SCREEN	200. SIEVE NIGHT	WATER CONTENT	OF COURSE UNIT WEIGHT (γ Floor (g/cm^3))	OF COURSE UNIT WEIGHT (γ Floor (kN/m^3))
76,2	SPT-1-2	1,50 - 3,45	49	15	6	1,86	18,2466
76,2	SPT-1-2	1,50 - 3,45	49	15	6	1,86	18,2466
76,2	SPT-3-4-5-6	4,50 - 9,45	45	17	7	1,86	18,2466
76,2	SPT-3-4-5-6	4,50 - 9,45	45	17	7	1,86	18,2466
76,2	SPT-3-4-5-6	4,50 - 9,45	45	17	7	1,86	18,2466
76,2	SPT-3-4-5-6	4,50 - 9,45	45	17	7	1,86	18,2466
76,2	SPT-7-8-9-10	10,50 - 15,45	43	18	6	1,86	18,2466
76,2	SPT-7-8-9-10	10,50 - 15,45	43	18	6	1,86	18,2466
76,2	SPT-7-8-9-10	10,50 - 15,45	43	18	6	1,86	18,2466
76,2	SPT-7-8-9-10	10,50 - 15,45	43	18	6	1,86	18,2466
76,2	SPT-1-2-3	1,50 - 4,95	47	20	7	2	19,62
76,2	SPT-1-2-3	1,50 - 4,95	47	20	7	2	19,62
76,2	SPT-1-2-3	1,50 - 4,95	47	20	7	2	19,62
76,2	SPT-4-5-6-7	6,00 - 10,95	47	4	6	0	19,62

CHAPTER 4

4. RESULTS AND DISCUSSION

4.1. SPT Maps

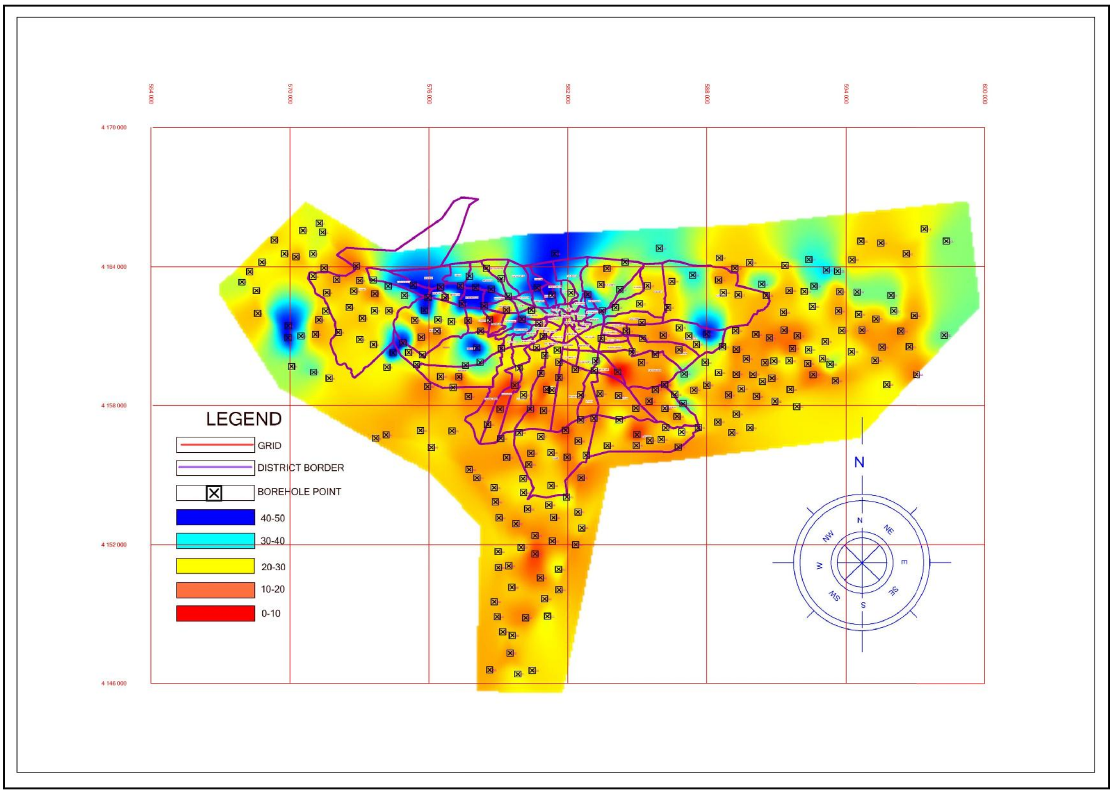


Figure 4.1. SPT-N in Study Area (4,5 m, 3. samples)

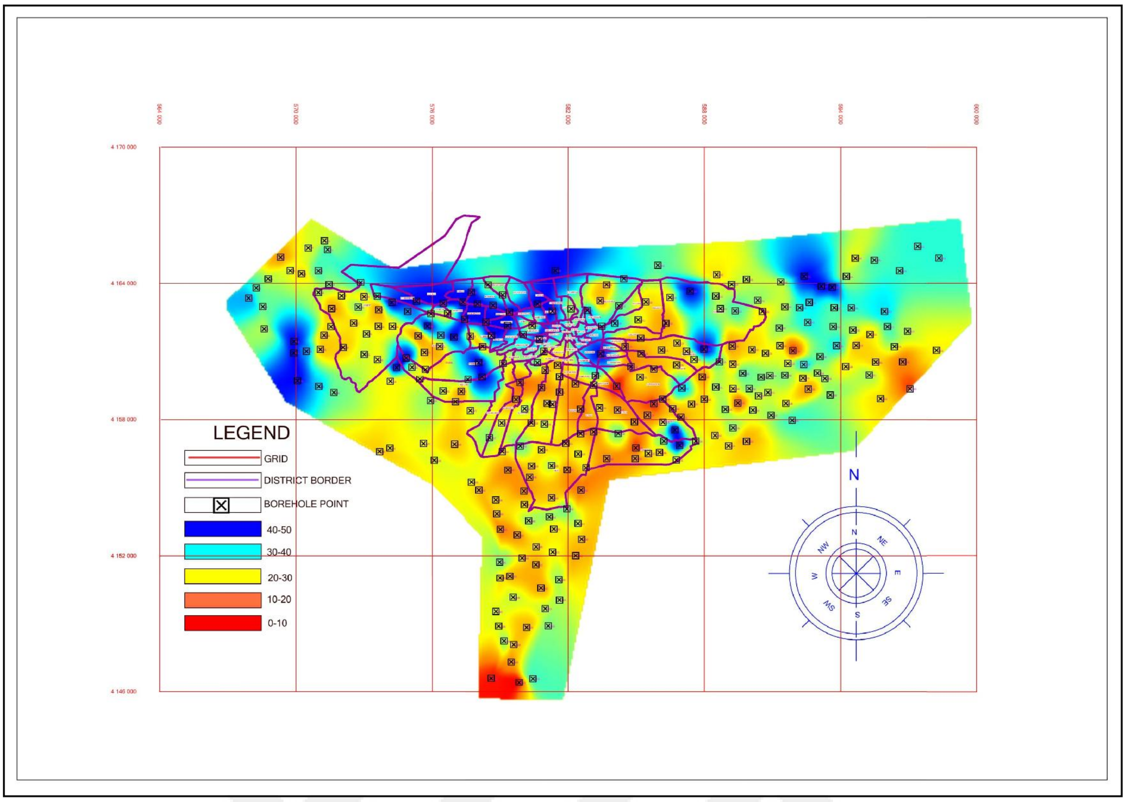


Figure 4.2. SPT-N in Study Area (7,5 m, 5. samples)

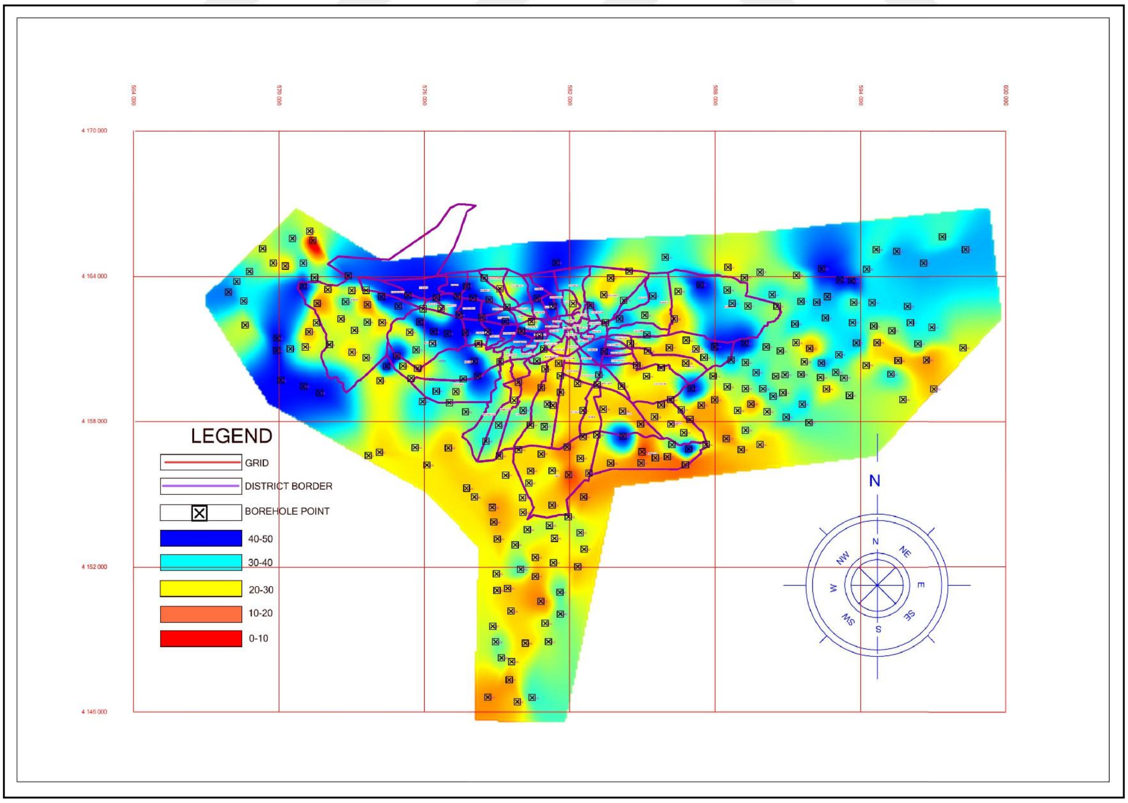


Figure 4.3. SPT-N in Study Area (15 m, 10. samples)

4.2. Bearing Capacity Maps

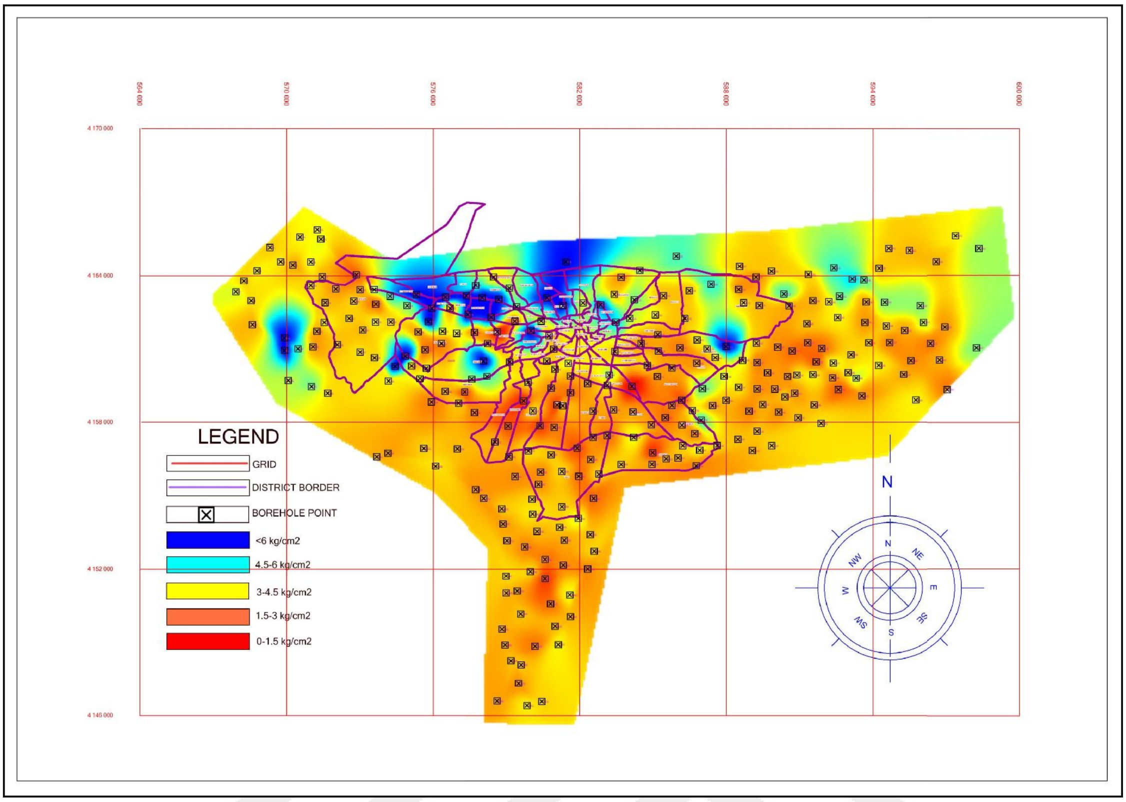


Figure 4.4. Bearing capacity in Study Area (4,5 m, 3. samples)

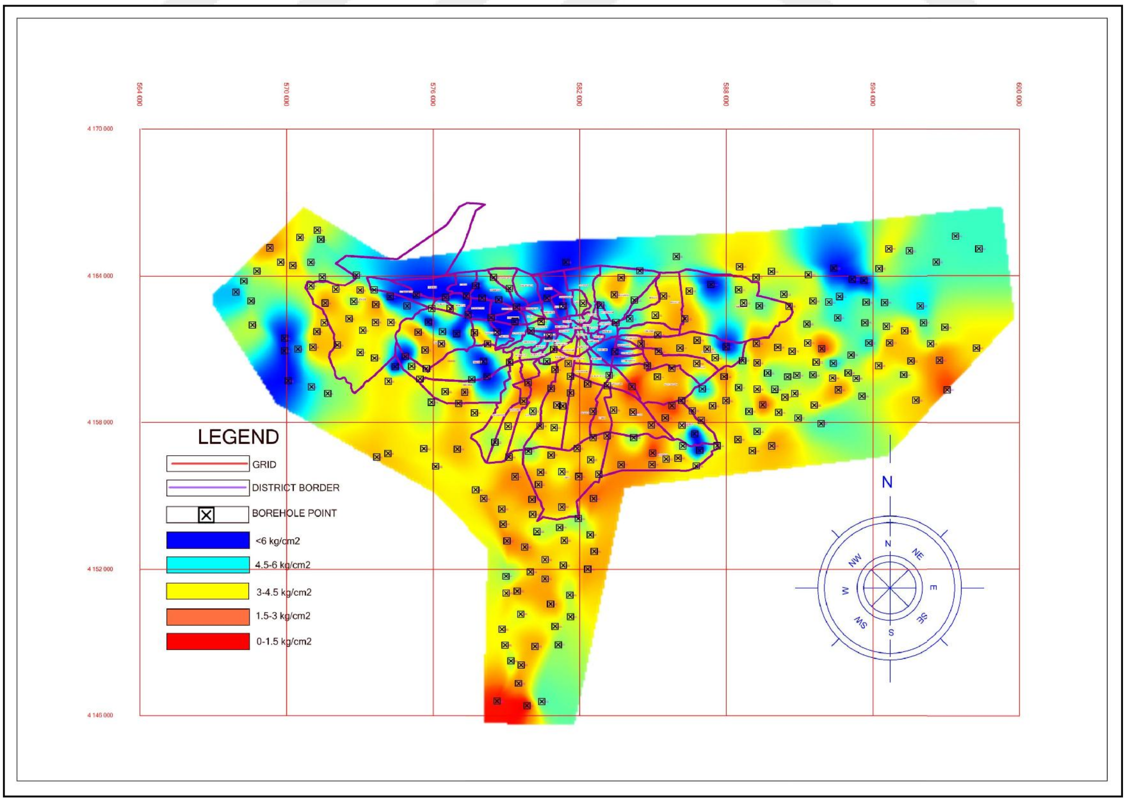
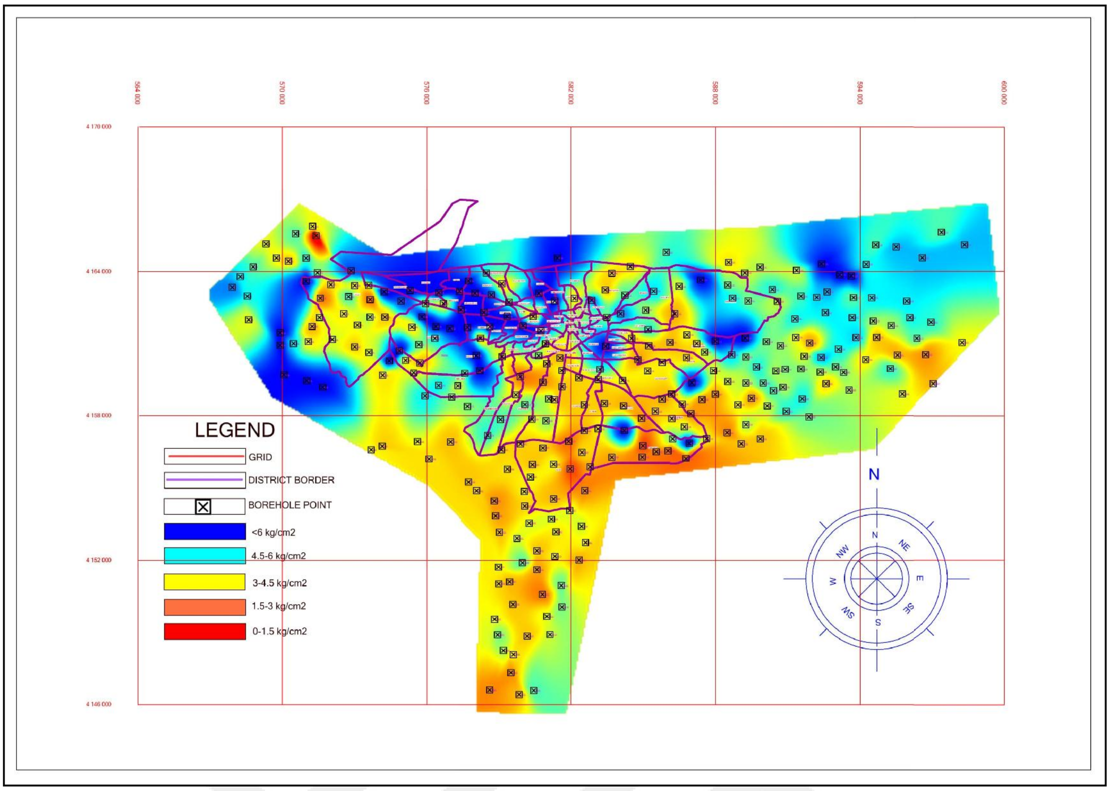


Figure 4.5. Bearing capacity in Study Area (7,5 m, 5. samples)



Figre 4.6. Bearing capacity in Study Area (15 m, 10. samples)

4.2. Fine Percentage Maps

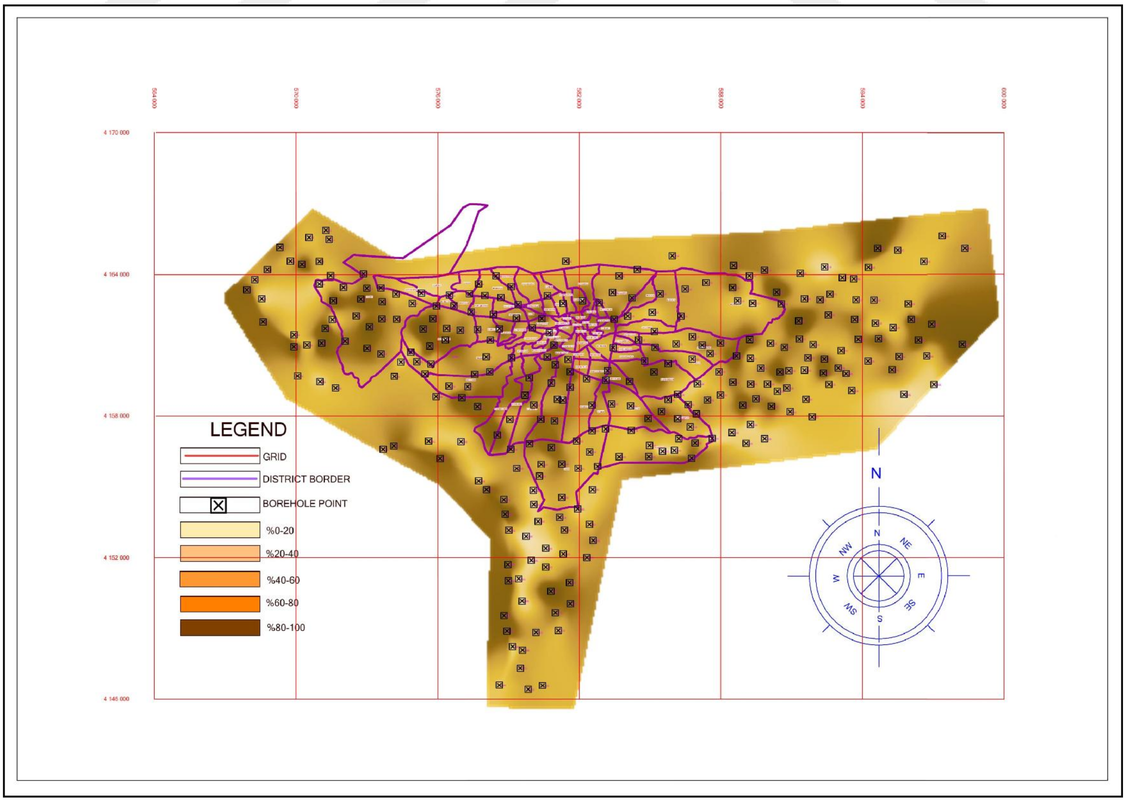


Figure 4.7. Fine Percentage in Study Area (4,5 m, 3. Samples)

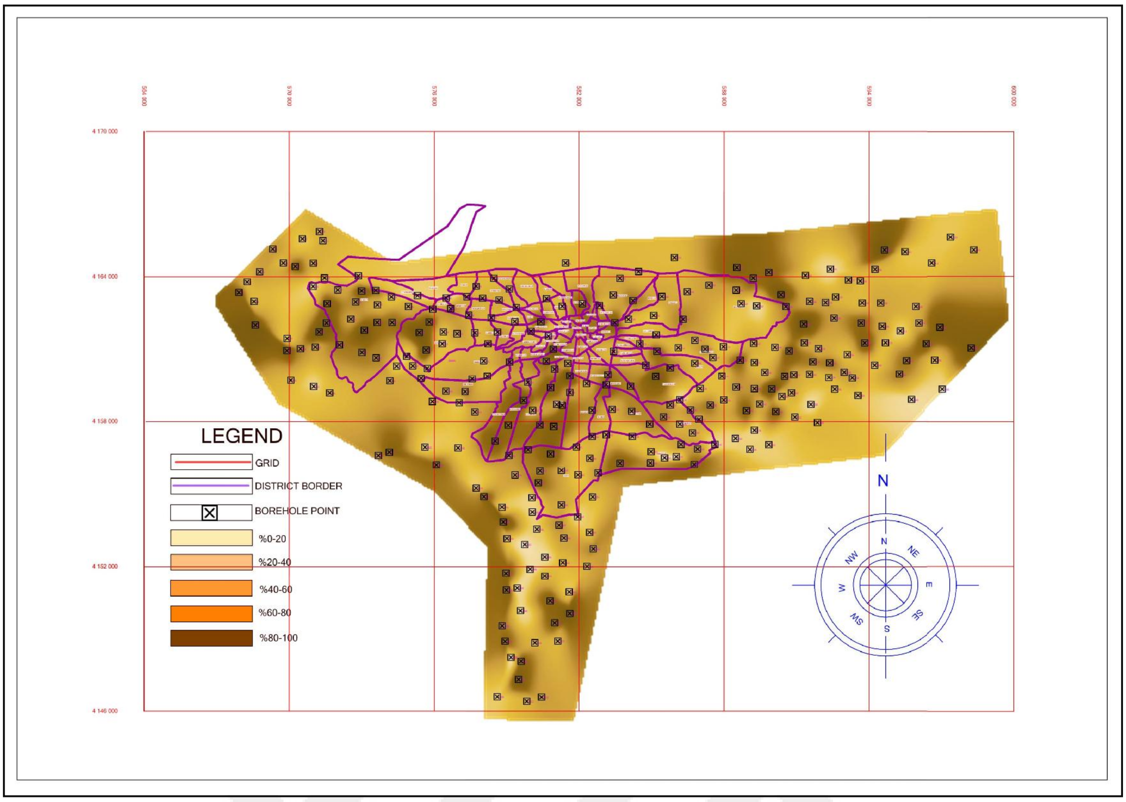


Figure 4.8. Fine Percentage in Study Area (7,5 m, 5. Samples)

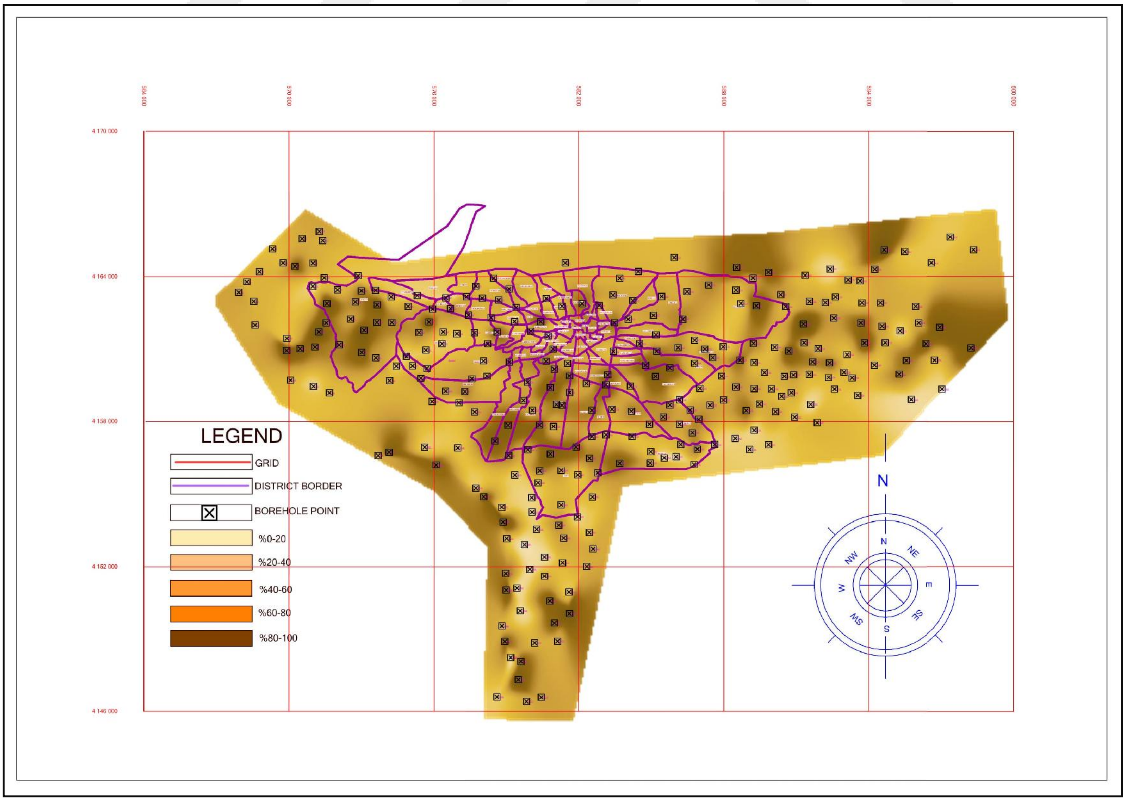


Figure 4.9. Fine Percentage in Study Area (15 m, 10. samples)

4.2. Water Content Maps

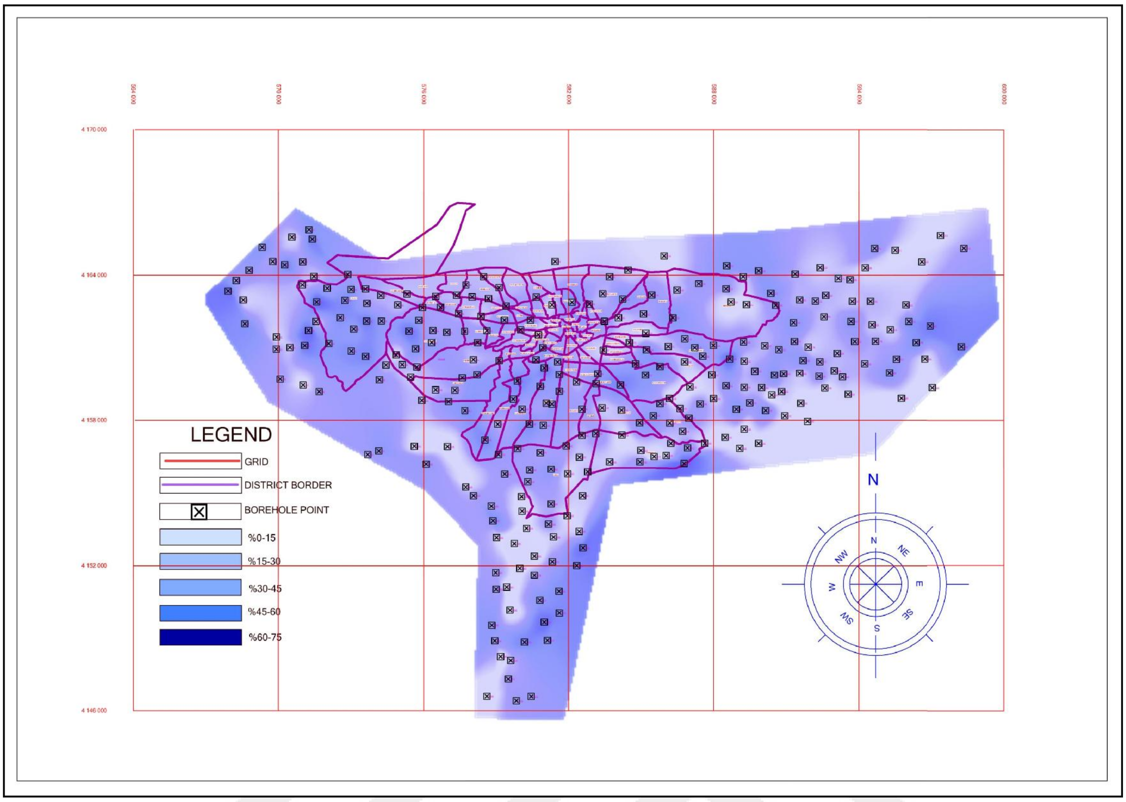


Figure 4.10. Water content in Study Area (4,5 m, 3. Samples)

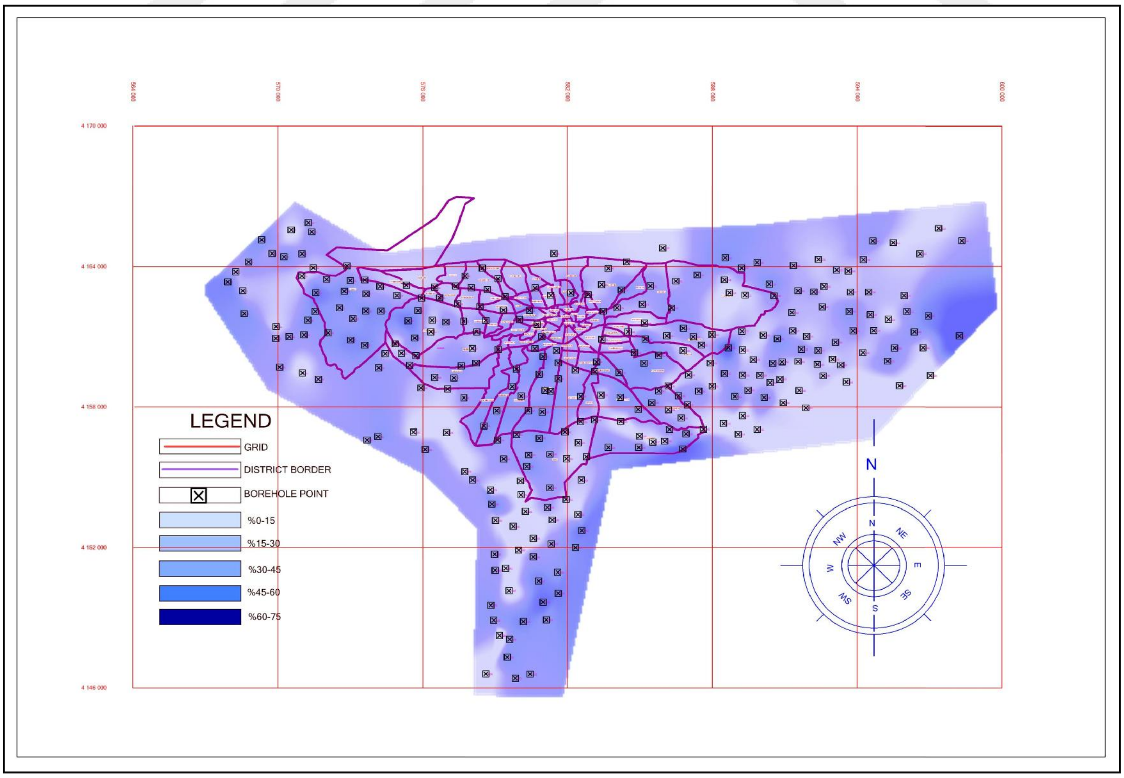


Figure 4.11. Water Content in Study Area (7,5 m, 5. Samples)

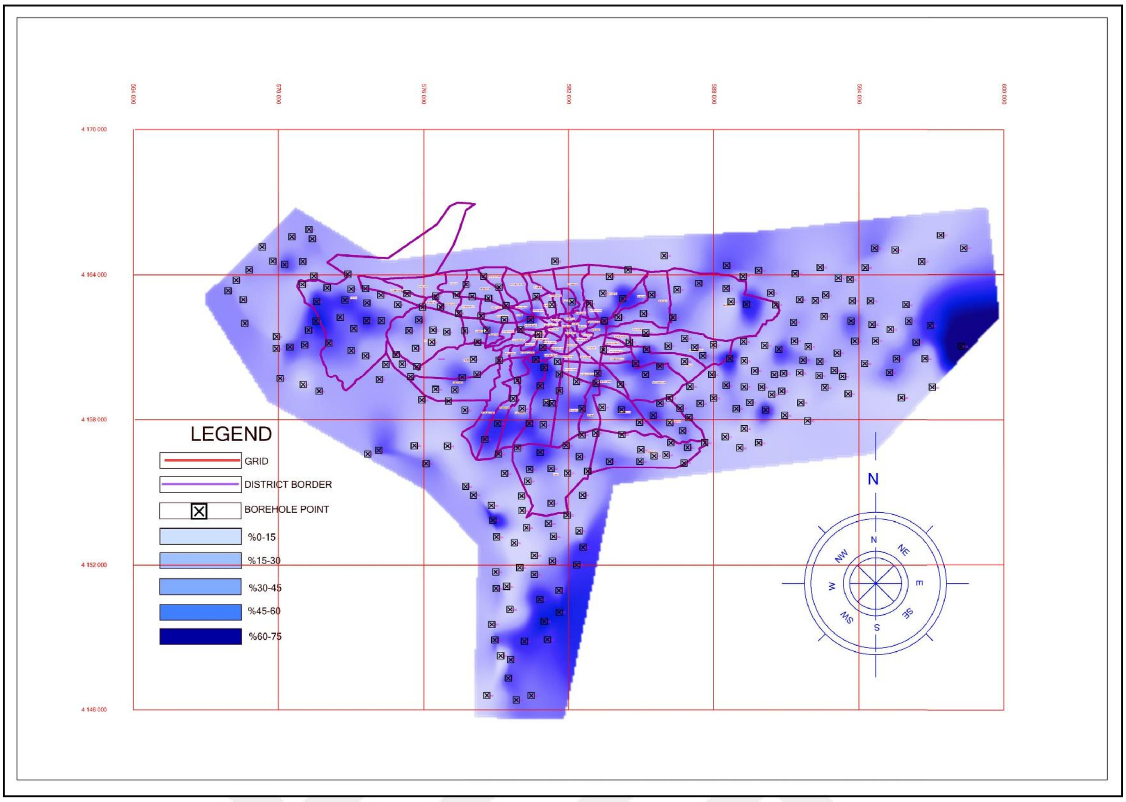


Figure 4.12. Water Content in Study Area (15 m, 10. samples)

4.5. Soilwater Level Maps

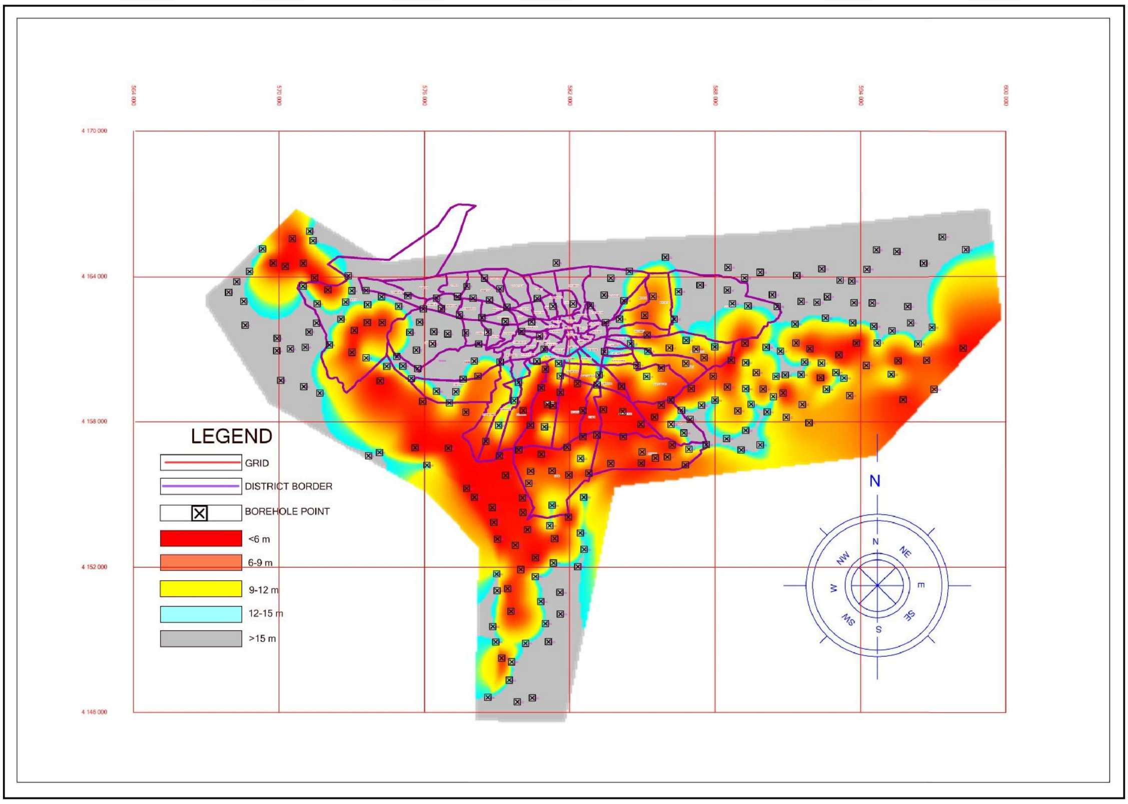


Figure 4.13. Soil Water Level in Study Area

4.6. Liquefaction Potenial Maps

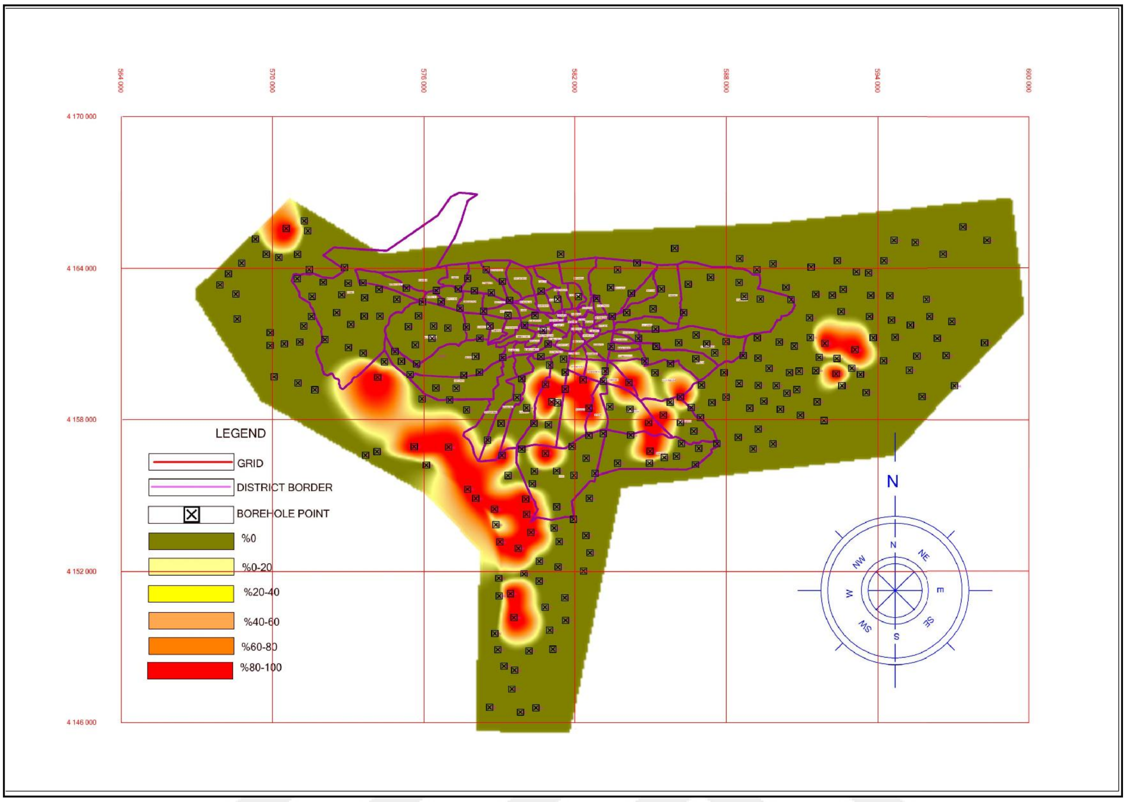


Figure 4.14. Liquefaction Risk in Study Area (4,5 m – 3. samples)

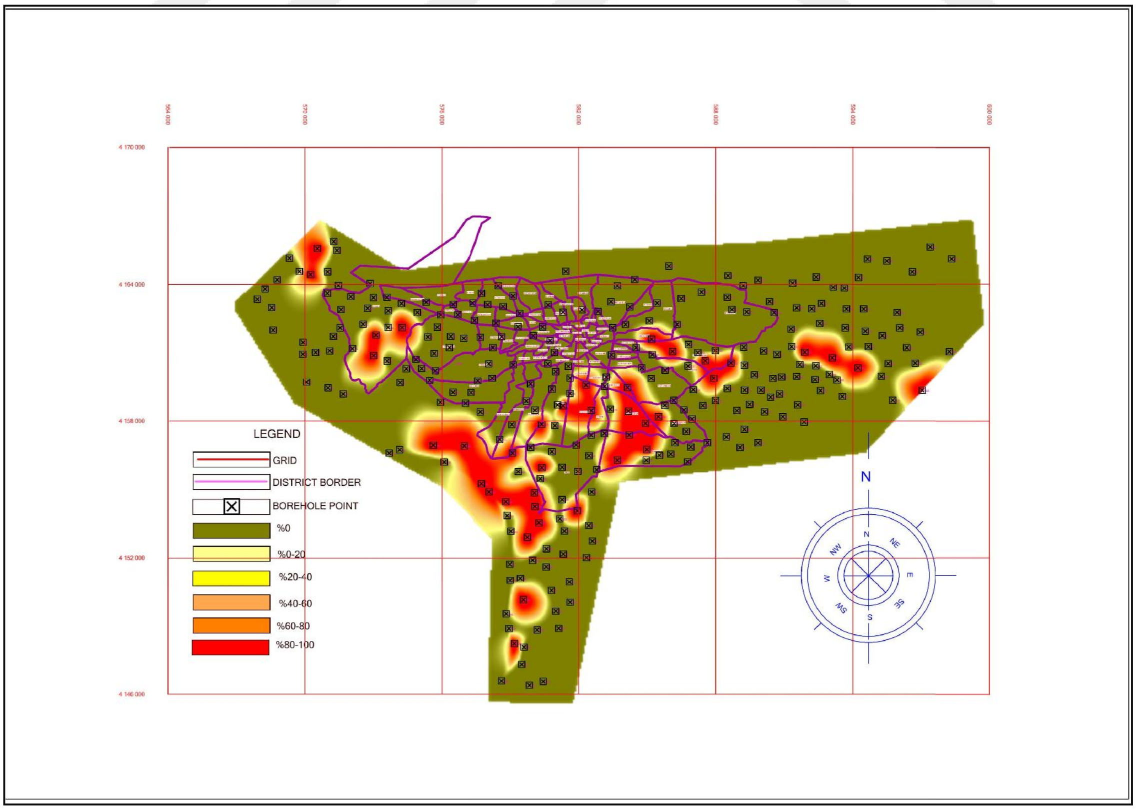


Figure 4.15. Liquefaction Risk in Study Area (7,5 m – 5. samples)

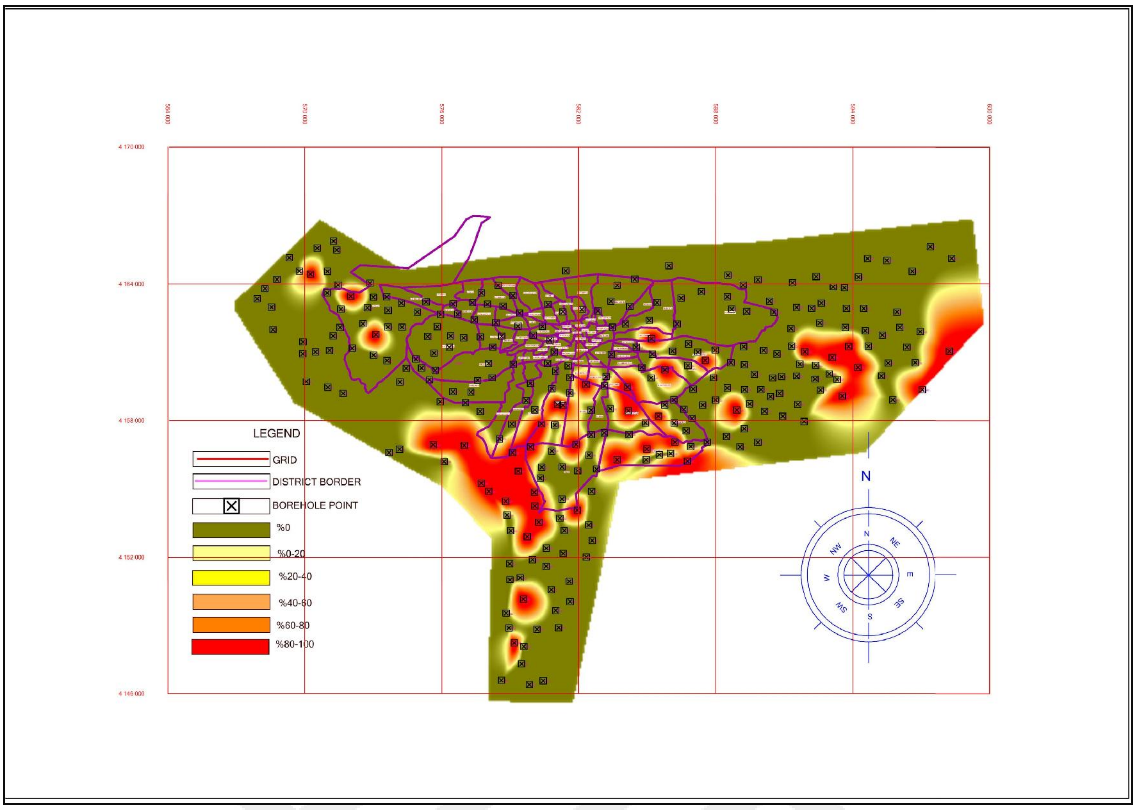


Figure 4.16. Liquefaction Risk in Study Area (13,5 m – 9. samples)

4.7. Shear Wave Velocity Maps

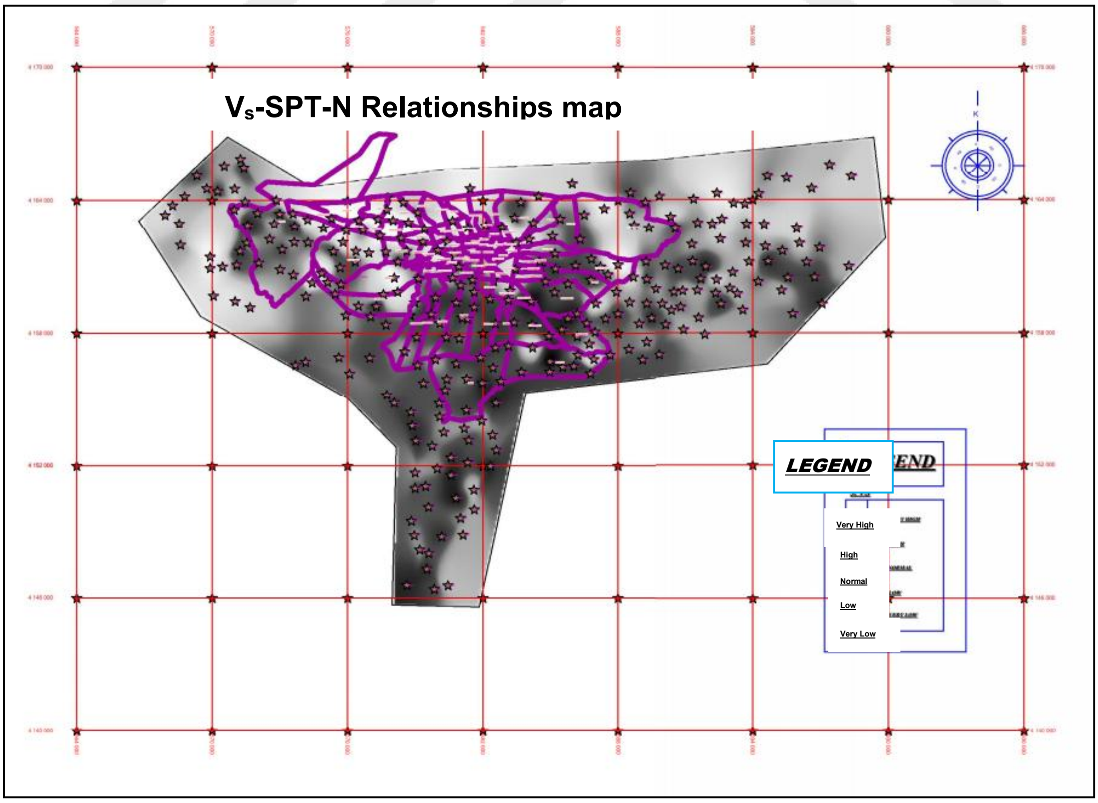


Figure 4.17. V_s-SPT-N Relationships in Study Area

Figure 4.4, 4.5 and 4.6 present the bearing capacity of Kahramanmaraş. As it can be seen from the figures/maps, the North of the city which is a mountein area has a higher bearing capacity. On the other hand the South of the city has a lower bearing capacity . This could be because of the high soilmater level and high fine content of the suth area.

Figure 4.7, 4.8 and 4.9 presents the fine contents of the city Kahramanmaraş. The dark areas shows that areas. From the legend of the maps, the fine percentage of the city could be observed.

CHAPTER 5

5. CONCLUSIONS

In order to maintain regular urbanization and secure housing, it is necessarry to carry out geological and geotechnical surveys for determining area's availability for building before preparing construction plans. Depending on these surveys, engineering geological maps are prepared. It is known that Kahramanmaraş is in Turkey Earthquake Map in 1st level and has high risk because it practiced a 6,4 earthquake in the past. The content of engineering geological map depends on why the map is prepared. In this paper, the earthquakes possible to affect Kahramanmaras, a geological engineering map has been prepared.

Liquefaction risk studies include; regional risk analysis, local risk analysis and geological, geotechnical and geophysical studies to represent the region. In this study, data obtained from soil boring, SPT, field studies and labaratory studies are interpretted with the help of GIS program. In the evaluation of soil studies' data and analysis, using 2-D GIS permits to inquire more realistic. Thus all soil data are edited and modelled for 2-D GIS program. The maps created at the end are SPT-N map, soil granul size distribution map, water content map, soil water level map, bearing capacity map and the most important liquefaction potential map. By using these maps and different data, an engineering geological map has been developped based on Kahramanmaras settlement's earthquake and soil qualifications. By interpreting these maps, the places with or without liquefaction risk can be determined.

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APPENDIX

T.C.
KAHRAMANMARAŞ BÜYÜKŞEHİR BELEDİYE BAŞKANLIĞI
İmar ve Şehircilik Dairesi Başkanlığı
Planlama Şube Müdürlüğü

Sayı : 59117952- 310-05.02-2429/20577 25.12.2015
Konu : İmar planı

ABDULLAH CANPOLAT
Dulkadiroğlu Belediye Başkanlığı
Dulkadiroğlu/KAHRAMANMARAŞ

İlgi: 25/12/2015 tarih ve 16652-6840 sayılı dilekçeniz.

İlgi sayılı dilekçe ile İlimiz Merkez Mahallerine ait 1/1000 ölçekli uygulama imar planına esas oluşturacak, zemin etüt tahkiklerinin, verilerinin ve dökümanlarının Üniversite Yüksek Lisans tezinde akademik çalışmalar için tarafınıza verilmesi istenmektedir.

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Bilgi ve gereğini rica olunur.

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