"CONSTRUCTION SCOPES ON AN OLD AND ABANDONED OPEN SOLID WASTE DUMP SITE IN HILLY AREAS"

A Thesis

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

IN

CIVIL ENGINEERING

With specialization in

ENVIRONMENTAL ENGINEERING

Under the supervision of

DR. RAJIV GANGULY

(ASSOCIATE PROFESSOR)

AND

MR. SAURABH RAWAT

(ASSISTANT PROFESSOR)

By

UJJVAL CHAUHAN

(152756)

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173 234

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CERTIFICATE

This is to certify that the work which is being presented in the thesis titled **"CONSTRUCTION SCOPES ON AN OLD AND ABANDONED OPEN SOLID WASTE DUMP SITE IN HILLY AREAS"** for partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in "**ENVIRONMENT ENGINEERING"** and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out By Ujjval Chauhan (Enrolment No. 152756) during a period from July 2016 to May 2017 under the supervision of **Dr. Rajiv Ganguly** Associate Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: - ………………………

Dr. Ashok Kumar Gupta	**Dr. Rajiv Ganguly**	**Mr. Saurabh Rawat**	**External examiner**
Professor & Head of Department	Associate Professor	Assistant Professor	
Department of Civil Engineering, JUIT Waknaghat	Department of Civil Engineering, JUIT Waknaghat	Department of Civil Engineering, JUIT Waknaghat	

<u>DECLARATION</u>

I hereby declare that the work reported in the M.tech thesis entitled "**CONSTRUCTION SCOPES ON AN OLD AND ABANDONED OPEN SOLID WASTE DUMP SITE IN HILLY AREAS"** submitted at **JayPee University of Information Technology, Waknaghat, Solan(H.P)** is an authentic record of my work carried out under the supervision of **Dr Rajiv Ganguly.** I have not submitted this work elsewhere for any other degree or diploma.

Ujjval Chauhan

Department of Civil Engineering

JayPee University of Information Technology

Waknaghat, Solan(H.P)

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ABSTRACT

With the continuous population growth driven by higher birth rate than death rate, increased demand for developable spaces in urban areas have became a major issue of concern. So this ceaseless increase in population has created increased interest in construction on top of landfills.

This study embraces experimental design to find out the suitability of abandoned solid waste site (ASWS) for any construction activity. Geotechnical properties of soil samples of ASWS and adjoining soil samples are measured at a depth of 1.0, 2.0, 3.0, 5.0, 8.0 m to investigate the difference in properties of abandoned solid waste site soil from natural soil. The soil samples were firstly determined for their nature and type and then subjected to direct shear test to find out cohesion and angle of internal resistance. Data collected was used to calculate ultimate bearing capacity which showed a huge variation. This is due to the effects of 'reinforced earth scenario' *i.e.* unusual high strength spots caused by mix matrices of soil and non-soil materials and unnoticed randomly distributed weak spots. Further Settlement was calculated by applying surcharge loading and the results showed a larger settlement value than allowable limits making the landfill site unsuitable for any hard top use.

CHAPTER 1

INTRODUCTION

1.1 General

India is a second most populated country in the world with a continuous increase in population year by year. With this continuous increase in population the solid waste generation is also increasing with a constant rate. Despite rapid growth of economy, urban solid wastes management has always been a neglected environmental area in India as well as other developing nations. There are number of methods available for the management of solid waste like composting, incineration, landfill, mechanical biological treatment, pyrolysis, refused derived fuel (RDF), waste autoclave, waste to energy etc. Despite of so many methods for waste management solid waste landfill is most common and preferred method for solid waste management because of its simplification and economic feasibility. Some of the other reasons for use of landfill for solid waste management included the low calorific value of municipal solid waste of India, moisture content range which makes it unsuitable for incineration without pre-treatment of waste and hence make it uneconomic. Due to large area requirement for processes like composting and lack of skills most of the solid waste is dumped in open or in an engineered landfill site. Moreover a certain fraction of waste which is as a refuse of other treatment methods is always required to be dumped in a landfill because of no other feasible methods. Hence landfill has become as the most important and adopted method for management of solid waste. With this increased practice of use of landfill in urban areas, the post closure usage of landfill have become a major topic to consider as there is immense scarcity of developable lands available in urban areas to meet the requirement of increasing population and hence any piece of land can't be allowed to waste.

"Can I build my house on an old abandoned solid waste dump site" this was a question asked by a non-professional in civil engineering and speaks of doubts and distrust about the use of abandoned solid waste dump site. This has been the general feeling in the developing world until 1990s when the need of waste management and the use of abandoned solid waste dump site started receiving inputs from engineering fields.

When talking about abandoned solid waste dump site, we all know that there are things that are different and unnatural about this site which make construction activities on any such site a topic of study.

Shimla is the capital of the Indian state of Himachal Pradesh located at an elevation of 2276m.With increase in population solid waste generation of Shimla city is continuously increasing year by year. For the purpose of dumping domestic solid waste a valley or trench type of landfill was adopted as due to greater degree of slope. Municipal solid waste (MSW) was disposed in an un-engineered open landfill situated in Lal Pani of Shimla city. This site became total abandoned in year 2014 and an alternate site located near Tutu is used for disposal of MSW. Currently a waste-to-energy plant is being installed for solid waste management to be functional by year 2018.

This thesis is a case study which aims to investigate the suitability this abandoned solid waste site of Lal pani for any construction activities. The landfill site under studies is an un-engineered landfill site which has been left over without any post closure activities.

1.2 Study area

Shimla is the capital of the northern Indian state of Himachal Pradesh located at Latitude 31.1048°N, longitude 77.1734°E. This town is located at an elevation of 2276m. The site investigated in this study is an abandoned solid waste dump site located in Lal pani of Shimla city. This site was used as an open dumpsite to dispose of solid waste of Shimla city till year 2014. Following are the figures showing the above mentioned study area Fig. 1(a) shows the map of Shimla city and Fig. 1(b) shows the landfill site under study.

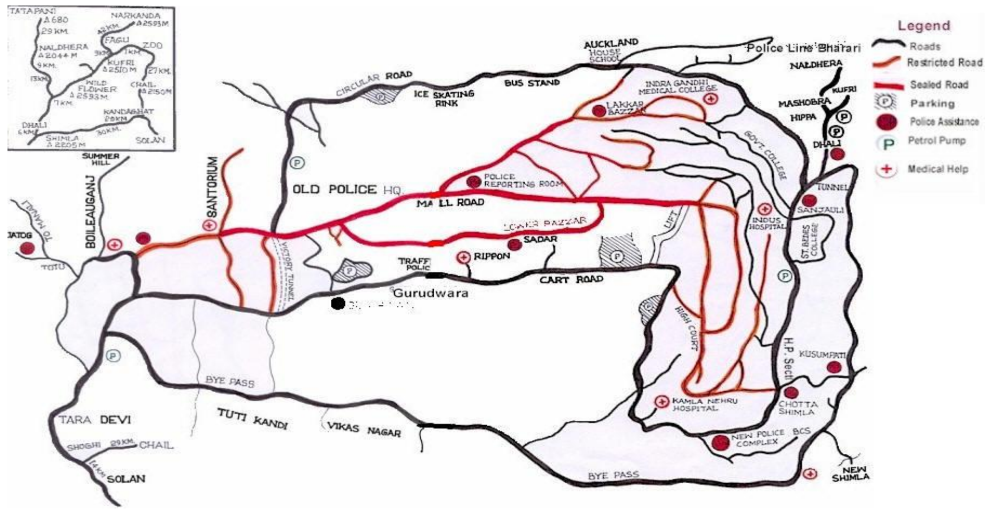

Figure 1(a): Map of Shimla City

Ref: http://hpshimla.nic.in/sml_maps.html

Figure 1(b) – Map of Shimla city showing landfill site

Ref: https://www.google.co.in/maps/place/Shimla

1.3 Need of the study

Shimla is a small town with rapid growth of population in urban areas so the need for developable lands is also increasing. Moreover with increase in population there is an increase in solid waste generation resulting in the requirement of more land for dumping/management of solid waste or an alternative method for MSW disposal.

So with this increased demand for land, this land which is used for dumping solid waste can't be allowed to waste without any post closure activities.

Several potential failures of structure on landfill site have been recorded before 2005 resulting in a death of about 600 peoples and causing a major threat to environment [1]. Despite of all these challenges associated with post-closure development of landfill both soft and hard top usage of old landfills are becoming common all over the world and various researches have been done for abandoned solid waste site soils in India also.

Considering the above factors this case study was adopted to find out the suitability of old abandoned landfill site for any post closure activities.

1.4 Objectives of the study

1 The initial objective of this study focuses on the collection of samples from different test points at different depths for detailed geotechnical investigation of abandoned municipal solid waste site soil and their comparison with nearby natural soil data.

2 The primary objective of this study is to calculate long term settlement of MSW site due to surcharge pressure (post closure activity) and overburden soil pressure.

1.5 Scope of the study

1. The present study focuses on the detailed geotechnical investigating of the abandoned solid waste dump site and prediction of long term settlement due to any surcharge pressure. The grain size determination was limited to use of sieve analysis. Further studies can focus on the alternative method of particle size determination i.e. hydrometric analysis which can thereof result in slight variation of results.

2. This study is limited to use of a single model to predict long term settlement due to surcharge load various other models can also be used to predict settlement.
3. Moreover there is a need of study to find out appropriate gas protection measures for any constructed structures which was not included in this study.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Literature review provides the summary of the published research literature relevant for this study. In this project, under-mentioned literature presents an objective and critical summary of work being carried out on solid waste landfill site. The purpose of literature review is to know research done and its future significance on this topic.

2.2 Geotechnical investigation

Under-mentioned literature shows the published research for geotechnical investigation of municipal solid waste site soil.

2.2.1 Can I Build my House on an Old and Abandoned Open Solid Waste Dump Site? , Ibrahim M. O., Abdul U. B., Otaru K. U. [1]

This study adopted experimental design for investigation of the suitability of abandoned solid waste site soil (ASWSS) for building construction. Geotechnical properties of ASWSS and abutting characteristic soil (NS) at depths 1.5, 2.0, 2.5, 3.0 and 3.5 m were acquired from three test focuses in Kaduna, Nigeria. The variation of geotechnical properties of ASWSS to that of NS was acquired by performing various laboratory tests. Sulphate resistant cement, large reinforced concrete basement or foundations covering large areas and a minimum foundation depth of 2.0 m are recommended for all structural foundations built on abandoned solid waste sites. The traditional method used for site examination and treatment of soil information have demonstrated lacking in getting the correct geotechnical capacity of ASWSS. The unusual variation of abandoned solid waste site data explains the presence of weak zones and 'reinforced earth scenarios' in solid waste site soil. The levels of degradation of ASWSS that have spent over twenty

(20) years of abandonment no more threaten the ultimate or serviceability performance of foundation members. Low values of safety indices of foundation designs on ASWSS showed clearly that it is unsuitable for heavy structures. However, light and minor structures can be sustained with relevant design techniques.

2.2.2 Construction on former landfills , A. Bouazza, E. Kavazanjian Jr. [13]

The objective of this study was to investigate the suitability of former landfill site for both hard uses includes roadway, buildings and infrastructure development and soft uses include golf courses and other recreational facilities (athletic fields). The building challenges related with old landfills incorporate basic difficulties, for example, moderation of blast and wellbeing dangers and air, soil, and groundwater impacts. These challenges include accommodating the total settlements typically associated with landfills and controlling the migration of landfill gas. Shallow foundation systems for construction on top of landfills are typically limited to relatively light structures one or two stories tall, due to settlement considerations. Deep foundations bearing on firm strata beneath the waste may be used to support heavier structures. However these deep foundation systems are generally limited to landfills that do not have engineered bottom liner systems. Despite the substantial engineering challenges associated with building on old landfills, an increasing number of such projects have been successfully completed. Case histories depict the fruitful utilization of building standards to oblige these difficulties for both hard and delicate post conclusion employments.

2.2.3 Geotechnical Properties of Waste Soil from Open Dumping Area in Malaysia , Nur Irfah M. Pauzi, Husaini Omar, Zainuddin M. Yusoff [7]

This study shows that waste soil consists of waste materials such as concrete debris, wood , plastic and other materials. The heterogeneous waste soil makes the geotechnical properties difficult to analyze and categorize. Various laboratory tests were conducted to determine various geotechnical parameters.

The direct shear test the values of cohesion ranges between 2 kPa-4kPa and angle of internal friction between 14^{o}-27^{o}. Based on tri-axial test the cohesion values is 3kPa and angle of internal friction lies between 0^{o}-10.5^{o}

2.2.4 Current State of the Practice of Construction on Closed Landfill Sites , Claire Odud.[16]

This research paper concentrate on the geotechnical aspects of the developments on closed landfill sites. It addresses such subjects as site improvement that is typically done before development can begin. This research addresses the configuration issues that need to represent the compressibility and low bearing limit of the waste material underlying the construction. To provide sufficient bearing capacity, pile foundations are typically used. The downward force on the pile foundation due to waste settlement is a major problem. Natural prosperity is in like manner an important issue in such improvement in light of the way that any break of the landfill direction structure would endanger general prosperity. Construction on closed landfill sites therefore requires careful planning, and design to account for the characteristics of the waste as well as health and safety issues.

2.2.5 Solar Power Installations on Closed Landfills: Technical and Regulatory Considerations , Gabriel Sampson.[14]

This paper examines the present practices of solar energy developments on abandoned landfills using the following focal areas: (1) landfill technical and engineering considerations (2) solar power system considerations with respect to landfill applications, (3) regulatory considerations. Research results indicate that various engineering techniques and solar technologies are available to facilitate the placement of solar energy systems on closed landfills. Though this study focuses on the technical and regulatory affairs of constructing solar farms on closed landfills, it also has applications to the placement of solar energy systems in broader settings.

2.2.6 Investigation of Geotechnical Properties of the Soil Susceptible to Landslide , Lekshmi J Satheesh, Deepthy B.L.[3]

The objectives of this research work was to investigate the properties of the soil collected from the field to propose remedial measures that is to be taken to reduce the landslide fatalities. The geotechnical properties of the soil samples were analyzed. The mitigation method does not help in avoiding the landslide but helps to reduce the loss of life and damage to the property that can be caused due to the landslide.

2.2.7 Geotechnical characterization of abandoned dumpsite soil, Bello Afeez Adefemi, Adegoke Clement Wole[10]

In this study geotechnical investigation were carried out on an abandoned dumpsite soils from Orita-Aperin, Ibadam south-western Nigeria to determine the compressive strength of soil samples which is an important factor. The engineering tests such as size analysis, natural moisture content and specific gravity were carried out in line with the procedures of the British standard 1377 of 1990. The soil samples were found to contain kaolinite as the major mineral. The values of the unconfined compressive strength obtained were in acceptable limits for containment facilities.

2.2.8 Correlation of plasticity Index and compression index of Soil, Vikas Kumar Jain, Mahabir Dixit, Dr. R. Chitra [4]

In this paper an attempt has been made to explain the variation in the values of coefficient of consolidation with the different plasticity properties, though the liquid limit of the soil are nearly same. The conclusions drawn are based on the results obtained from remoulded soils. Based on the calculated results an equation has been derived to predict the values coefficient of consolidation in terms of shrinkage limit and plastic limits.

2.3 Settlement analysis

Under-mentioned literature includes the settlement calculation of MSW dumpsite using different models.

2.3.1 Parametric study of MSW Landfill Settlement model , G. L. Sivakumar Babu, Professor[6]

This study aims to develop and validate a constitutive model that accounts for primary compression, time dependent mechanical creep and biodegradation. The model developed was compared to the Marques (2001) model and Marques at el. (2003) model. The model enables the prediction of stress strain response and yield surfaces for three components of settlement: primary compression, mechanical creep, and biodegradation. The proposed model captures the time settlement response which is in general agreement with the results obtained from the other two reported models having similar features.

2.3.2 Settlement model of waste soil for dumping area in Malaysia, Nur Irfah Mohd Pauzi, Husaini Omar, Bujang Kim Huat, Halina Misran.[11]

This paper attempted to review past works on the settlement models of waste soil prediction using constitutive model for open dumping. This study considered four groups of published settlement model of municipal solid waste namely soil mechanic based model, empirical model, rheological model and settlement models which incorporated biodegradation e.g. Marques (2001) model, Marques at al. (2003) and developed a constitutive model for long term settlement prediction of open dumping.

2.3.3 Prediction of long-term municipal solid waste landfill settlement using constitutive model, G. L. Sivakumar Babu, Krishna R. Reddy, Sandeep K. Chouskey, Hanumanth S. Kulkarni [12]

This paper provides a constitutive model for prediction of long term settlement of municipal solid waste dump site incorporating the effects of time dependent biodegradation and mechanical creep based on the rheological model developed by Marques in year 2001 and 2003. The model parameters are calculated from laboratory test and data available from published literature. The prepared constitutive model is used to predict settlement of landfill due to incremental loading.

2.3.4 Analysis of long-term settlement of municipal solid landfills as determined by various settlement estimation methods, Hyun II park, Borinara park, Seung Lee.[15]

In this review, few existing waste settlement strategies are connected to examine the settlement information of nine metropolitan waste landfills. Results show that the individual estimation methods show an extensive variation in anticipating settlements in the new MSW landfills. Further, for the old landfills, majority of the estimation methods, with the exception of the extended soil model, shows low settlement possibilities.

2.3.5 Calibration of a coupled mechanical and biological model for landfill settlement prediction based on field monitoring data , G.F. Simoes, F.H.R. Da Silva, C.A.A Catapreta[8]

This paper gives the application of a one dimensional, coupled mechanical and biological model to evaluate the settlements in solid waste dump site. Two different types of settlement includes immediate settlement due to mechanical behaviour of waste and long term settlement due to biological decomposition caused by application of load. A model was prepared to predict the total long term settlement due to load application and was calibrated using two sets of data from Belo Horizonte landfill (Brazil) called AC-05. The results obtained from this model show a good representation of the field data.

2.3.6 Former Landfill and Disposal Site Investigations , Glenn K. Young[9]

This report was prepared by staff of the Department of Resources Recycling and Recovery to provide technical assistance to local governments and solid waste facility operations in investigating former landfills and disposal sites. Various case studies are presented in this paper to show how investigations were carried out to determine the approximate horizontal and vertical extents of abandoned landfill site.

2.3.7 Long- term settlement prediction of waste soil using Rheological model and coupled with Monte Carlo simulation, Nur Irfah Mohd Pauzi, Yao Choon Wai, Husaini Omar[2]

This study aims to predict the long-term settlement of waste soil using rheological model further the Monte Carlo simulation process is used for probability analysis in order to determine the safe settlement depth at the dumping sites. Three case studies were done and the total settlement was calculated using the model.

2.3.8 Compression Behavior of Municipal Solid Waste: Immediate Compression, A. Bareither, Craig H. Benson, Tuncer B. Edil[5]

This study presents an evaluation of scale effects, waste segregation, stress and waste decomposition on the immediate compression behaviours of municipal solid waste. Waste compressibility index (WCI) is a function of water content, dry unit weight and amount of biodegradable organic waste the variation in compression ratio is related to waste compressibility index (WCI).This study provides a predictive relationship of waste compressibility index and compression ratio.

2.4 Observations from literature review

1. Post-closure development of landfills includes both hard uses such as commercial buildings, and infrastructure facilities and soft uses such as golf courses, Nature Park and athletic fields.
2. Engineering challenges associated with the landfill redevelopment include foundation design. Due to the large settlement potential, landfill redevelopment using shallow foundations is generally restricted to low-rise structures of one or two stories with raft foundations.
3. One of the major engineering challenges associated with construction on former landfill is the control of landfill gas emission.
4. The level of degradation of ASWSS is considered as negligible after over twenty (20) years.
5. Geotechnical characterization of ASWSS should be obtained via a sampling plan that is generally more detailed than that of natural ground. It should be an attempt to capture the majority of site irregularities that are associated with ASWSS.
6. Gases such as carbon dioxide (CO2) and methane (CH4) are produced in most landfill sites. These gases can migrate into buildings or confined spaces and may accumulate to explosive concentrations.
7. Long term settlement prediction should be done using model that accounts for immediate settlement, mechanical creep and long term biological decomposition.
8. Various constitutive models are developed that accounts for immediate settlement, mechanical creep and long term biological decomposition. These models are based on a model developed by Marques in year 2001 which is a rheological model to account for primary and secondary compression mechanisms, governed by rheological parameters that also accounts for waste degradation.

CHAPTER 3
METHODOLOGY

3.1 Introduction

The objective of this research work is to investigate the geotechnical properties of an old abandoned landfill site of Shimla city which was completely closed in year 2013. This landfill site was an un-engineered landfill site where the solid waste of Shimla city was dumped without any pre-treatment and compaction. Waste loaded trucks directly used to enter the site and empty the waste followed by filling of soil and rocks which was done on daily basis to prevent un-hygienic conditions. Waste dumping was done without any segregation, and all types of domestic waste, small scale industrial waste, institutional waste, street cleaning wastes were dumped. The site selected for investigation is a part of this landfill site which was closed for about 6 years. Site selected is in the form of a rectangular area from where the soil samples are collected. The major objective of this research is detailed investigation of the geotechnical properties of this landfill site, their comparison with nearby natural soil and prediction of long term settlement using empirical models. As India is a developing country with rapid growth in population, so the land required for dumping of solid waste couldn't be allowed to waste without any post closure activity. There are number of landfill sites in India that have been abandoned years ago and no such research have been done as due to social un-acceptance. Many such studies have been done outside India and many such failures have been recorded but using this method of detailed evaluation which is used in this research it is possible to find out the corrected values of properties of municipal solid waste landfill site. The major cause of failure of structure over a landfill site is due to its foundation failure which is because of presence of weak spots in the landfill site and long term settlement of MSW. The properties of landfill site are varying with at different test points. Unusual high spots are caused by mix matrix of soil and non-soil materials and unnoticed randomly distributed weak spots are also present. Collection of samples in undisturbed state was a major problem in this research. SPT (standard penetration test) apparatus was unable to operate due to presence of rocks and no 'N' value could be determined, moreover undisturbed samples could not be collected because the split spoon sampler failed to work due to presence of rock strata.

3.2 Site investigation

Geotechnical site investigations include surface exploration and subsurface exploration of a site soil. Subsurface exploration usually involves soil sampling and laboratory tests of the soil samples retrieved. Whereas surface exploration can include geologic mapping, geophysical methods, and photo-grammetry, or it can be as simple as a geotechnical professional walking around on the site to observe the physical conditions at the site. To obtain information about the soil conditions below the surface, some form of subsurface exploration is required. Figure 2 shows the abandoned solid waste site of Shimla city.

Figure 2 - Abandoned Solid waste dump site of Shimla city.

3.3 Collection of samples

Collection of sample was done in two phases.

3.3.1 Phase 1

Sample collection from the landfill site was done by manual boring. 4 pit holes were made in form of a rectangle of approximately 8mx4m dimension in the landfill site. One pit hole was made in the centre of the rectangular area of the site. Figure 3 shows the pit hole in MSW site. One more pit hole was made in the nearby soil. Samples were collected from three different depths (i.e. 1.0m, 2.0m, and 3.0m) from all test points. Fifteen samples were collected from the abandoned landfill site soil naming A1, A2, A3, B1, B2, B3, C1, C2, C3, D1, D2, D3, E1, E2 and E3. Three samples were collected from the nearby natural soil naming N1, N2 and N3.

3.3.2 Phase 2

In phase 2 the samples were collected from the side slope of the landfill site using augur sampler at depths 5m and 8m from 6 different test points naming F1,F1,G1,G2,H1,H2.

Figure 3 – Pit hole for sample collection.

3.4 Grain size analysis (sieve analysis)[19]

Figure 4(a) – Sieve stack

Figure 4(b) – Weight measurement of retained samples in sieve

3.4.1 Introduction

A sieve analysis is a most common practice or procedure used (commonly used in civil engineering) to find the particle size distribution of a granular material in soil samples. The size appropriation is frequently of basic significance to the way the material performs being used. A sieve analysis can be performed on any type of non-organic or organic materials including sands, crushed rock, clays, granite, feldspars, coal, soil a wide range of manufactured powders, grain and seeds. Oven dried samples of soil weighing 500 g is passed through a sieve stack consisting 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.425mm, 0.3mm and 0.075mm sieves. The sieve stack is then placed in the mechanical shaker for 10-15 minutes and the mass of retained soil in each sieve is measured.

3.4.2 Results

Results from the sieve analysis are recorded in a tabular form as shown below

For determined test values from laboratory tests refer to annexure A.

SR. NO.	SAMPLE NO.	GRAVEL (%) 4.75mm Retained	SAND (%) Fraction - 4.75mm to 0.075mm	SILT AND CLAY (%) Passing 75 micron
1	A1	47.5	19.2	33.3
2	A2	55.4	21.6	23
3	A3	53.9	18.9	27.2
4	B1	47.5	19.2	33.3
5	B2	36.3	25.3	38.4
6	B3	34.5	33.2	32.3
7	C1	24.6	32.5	42.9
8	C2	17.6	41.3	41.1
9	C3	29.3	33.1	37.6
10	D1	47.3	25.7	27
11	D2	49.8	29.4	20.8

12	D3	62.5	18.1	13.4
13	E1	38.1	26.2	35.7
14	E2	26.8	29.4	32.5
15	E3	68.8	18.1	13.2
16	N1	54.6	20	25.4
17	N2	44.3	25.1	30.6
18	N3	66	22.2	11.8
19	F1	34.5	16.3	49.2
20	F2	24.2	23.3	52.5
21	G1	27.7	28.9	43.4
22	G2	27.5	21.2	51.3
23	H1	26.3	29.2	44.5
24	H2	23.4	26.9	49.7

Table 1 - Sieve analysis test results

3.5 Determination of moisture content

Figure 5 – Soil samples in oven.

3.5.1 Introduction

Moisture content is defined as the amount of water contained in soil. This method covers the laboratory determination of the moisture content of a soil as a percentage of its oven-dried weight. The method is based on removing soil moisture by oven-drying a soil sample till the weight remains constant. The moisture content (%) is calculated from the sample weight before and after drying.

3.5.2 Results

Moisture content of the soil samples are obtained using following equation [18].

$$w = \frac{(W2 - W3)}{(W3 - W1)} \times 100 \qquad (1)$$

Where;

w = Moisture content (%)

W1= Weight of empty container.

W2= Weight of container containing moist soil sample.

W3= Weight of oven dried soil sample and container.

Refer to annexure B for test values.

SR. NO.	SAMPLE NO.	MOISTURE CONTENT (%)
1	A1	5.04
2	A2	4.66
3	A3	4.8
4	B1	3.4
5	B2	4.6
6	B3	4.5
7	C1	5.02

8	C2	5.6
9	C3	3.98
10	D1	3.52
11	D2	3.6
12	D3	3.0
13	E1	4.2
14	E2	5.12
15	E3	4.03
16	N1	2.67
17	N2	3.1
18	N3	5.2
19	F1	6.9
20	F2	7.7
21	G1	6.79
22	G2	7.6
23	H1	5.99
24	H2	7.4

Table 2- Moisture content test results

3.6 Determination of specific gravity

Figure 6 – Recording the weight of pycnometer filled with sample and water.

3.6.1 Introduction

Specific gravity is defined as the ratio of the density of a substance to the density of a reference substance; equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume. The reference substance always water at its densest (4°C) for liquids; for gases it is air at room temperature (21°C). Specific gravity G is defined as the ratio of the unit weight (or density) of soil solids to unit weight (or density) of water. The knowledge of specific gravity is required in calculation of soil properties like void ratio, degree of saturation and also weight-volume relationship. Oven dried MSW soil sample weighing 200-300 g is obtained passing through 4.75mm sieve and poured into dry pycnometer of known weight. The weight of the pycnometer containing soil samples is measured. Further water is added to cover the soil and the pycnometer is well shaked to remove the entrapped air for about 10-20 minutes. After the air has been removed fill the pycnometer with water and weigh it. Now measure the weight of pycnometer filled with water to its top.

3.6.2 Results

Specific gravity of the soil samples is calculated using following empirical relation. [20]

$$G = \frac{W2 - W1}{(W2 - W1) - (W3 - W4)} \tag{2}$$

Where;

G = Specific gravity

W1= Weight of empty pycnometer

W2= Weight of pycnometer and soil sample

W3= Weight of pycnometer, soil sample and water

W4= Weight of pycnometer filled with water

For test values refer to annexure C

SR. NO.	SAMPLE NO.	Specific gravity
1	A1	2.01
2	A2	1.98
3	A3	1.9
4	B1	2.25
5	B2	2.1
6	B3	1.72
7	C1	2.2
8	C2	2.3
9	C3	1.78
10	D1	2.32
11	D2	2.12
12	D3	1.82
13	E1	2.4
14	E2	2.23
15	E3	2.02
16	N1	2.57
17	N2	2.52
18	N3	2.68
19	F1	1.98
20	F2	2.28
21	G1	2.06
22	G2	1.94
23	H1	2.01
24	H2	1.95

Table 3- Specific gravity test results

3.7 Direct shear test

Figure 7(a) – Direct shear test apparatus.

Figure 7(b) – Direct shear apparatus meter displaying load and displacement.

3.7.1 Introduction

The concept of direct shear is simple and mostly used for granular soils, sometimes on soils which contain some cohesive soil content. The cohesive soils have issues regarding controlling the strain rates to drained or un-drained loading.

In granular soils, loading can always assumed to be drained. A schematic diagram of shear box shows that soil sample is placed in a square box which is split into upper and lower halves. Lower section is fixed and upper section is pushed or pulled horizontally relative to other section; thus forcing the soil sample to shear/fail along the horizontal plane separating two halves. Under a specific Normal force, the Shear force is increased from zero until the sample is fully sheared. The relationship of Normal stress and Shear stress at failure gives the failure envelope of the soil and provide the shear strength parameters (cohesion and internal friction angle). The value internal friction angle and cohesion of the soil are required for design of many engineering problems such as foundations, retaining walls, bridges, sheet piling. Direct shear test can predict these parameters quickly.

3.7.2 Results

Values of shear stress are calculated using following equation [7].

$$\tau = \frac{\frac{(D_H \times 1000)}{9.81}}{36 \times (1 - \frac{DG}{3})} \tag{3}$$

Where;

τ = Shear stress (kg/cm^2)

D_H= Horizontal displacement (kN)

DG= Dial gauge readings (cm)

For values of displacement and dial gauge readings refer to annexure :

SR. NO.	SAMPLE NO.	NORMAL STRESS(kg/cm^2)	SHEAR STRESS (kg/cm^2)
1	A1	0.5	0.29
2	A1	1.0	0.33
3	A1	1.5	0.37
4	A2	0.5	0.21

5	A2	1.0	0.265
6	A2	1.5	0.32
7	A3	0.5	0.125
8	A3	1.0	0.16
9	A3	1.5	0.199
10	B1	0.5	0.24
11	B1	1.0	0.285
12	B1	1.5	0.33
13	B2	0.5	0.145
14	B2	1.0	0.20
15	B2	1.5	0.255
16	B3	0.5	0.175
17	B3	1.0	0.22
18	B3	1.5	0.285
19	C1	0.5	0.130
20	C1	1.0	0.195
21	C1	1.5	0.26
22	C2	0.5	0.265
23	C2	1.0	0.305
24	C2	1.5	0.352
25	C3	0.5	0.215
26	C3	1.0	0.265
27	C3	1.5	0.315
28	D1	0.5	0.25
29	D1	1.0	0.31
30	D1	1.5	0.36
31	D2	0.5	0.185
32	D2	1.0	0.225
33	D2	1.5	0.26
34	D3	0.5	0.15

35	D3	1.0	0.19
36	D3	1.5	0.23
37	E1	0.5	0.295
38	E1	1.0	0.34
39	E1	1.5	0.38
40	E2	0.5	0.145
41	E2	1.0	0.19
42	E2	1.5	0.235
43	E3	0.5	0.207
44	E3	1.0	0.245
45	E3	1.5	0.285
46	N1	0.5	0.31
47	N1	1.0	0.37
48	N1	1.5	0.43
49	N2	0.5	0.265
50	N2	1.0	0.32
51	N2	1.5	0.38
52	N3	0.5	0.21
53	N3	1.0	0.27
54	N3	1.5	0.33
55	F1	0.5	0.275
56	F1	1.0	0.315
57	F1	1.5	0.355
58	F2	0.5	0.29
59	F2	1.0	0.325
60	F2	1.5	0.365
61	G1	0.5	0.23
62	G1	1.0	0.275
63	G1	1.5	0.315
64	G2	0.5	0.26

65	G2	1.0	0.295
66	G2	1.5	0.335
68	H1	0.5	0.295
69	H1	1.0	0.33
70	H1	1.5	0.365
71	H2	0.5	0.26
72	H2	1.0	0.32
73	H2	1.5	0.36

Table 4 - Values of Shear stress at different normal stress

3.7.3 Plots between normal stress and shear stress

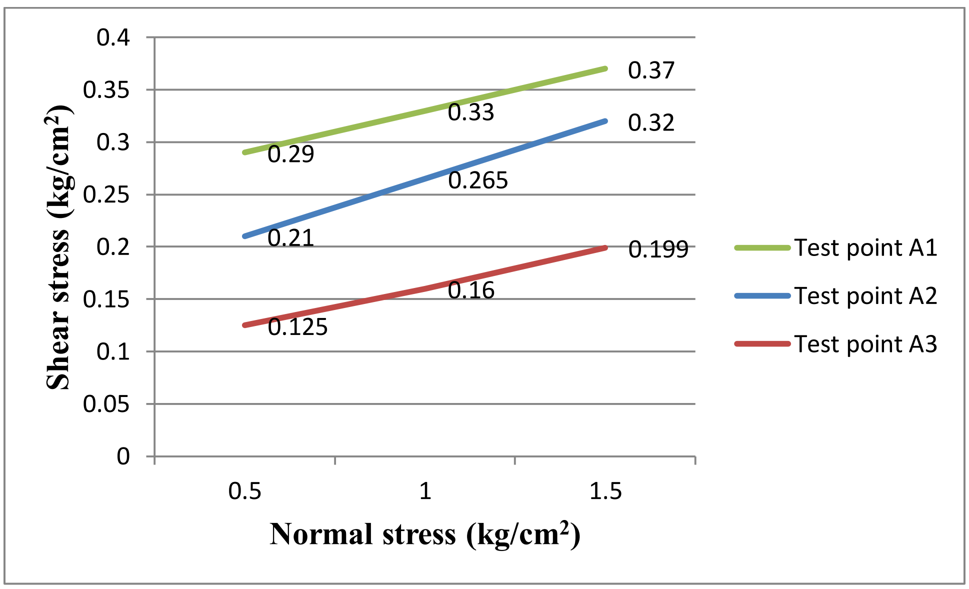

Figure 8(a) – Plot between Normal stress and shear stress for test point A

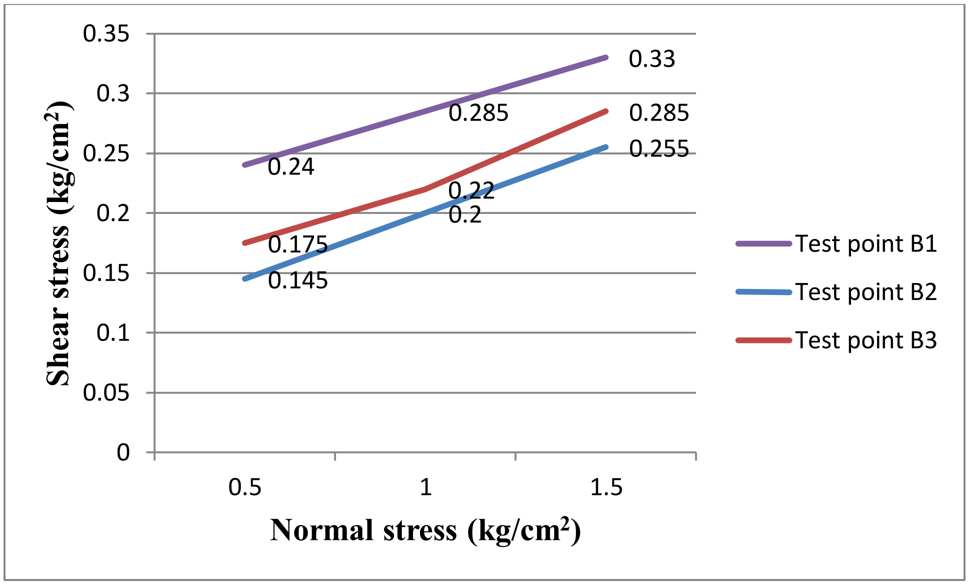

Figure 8(b) – Plot between Normal stress and shear stress for test point B

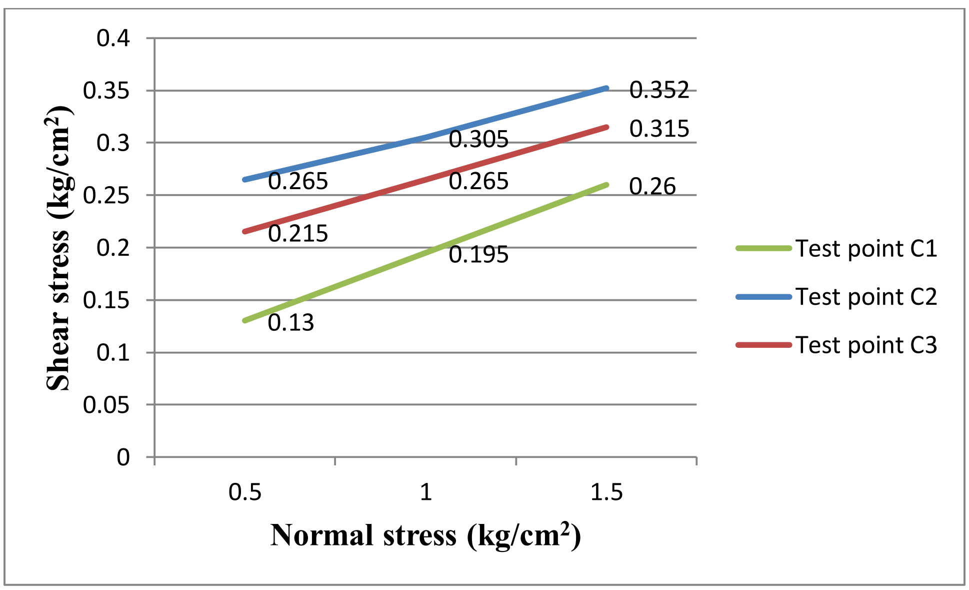

Figure 8(c) – Plot between Normal stress and shear stress for test point C

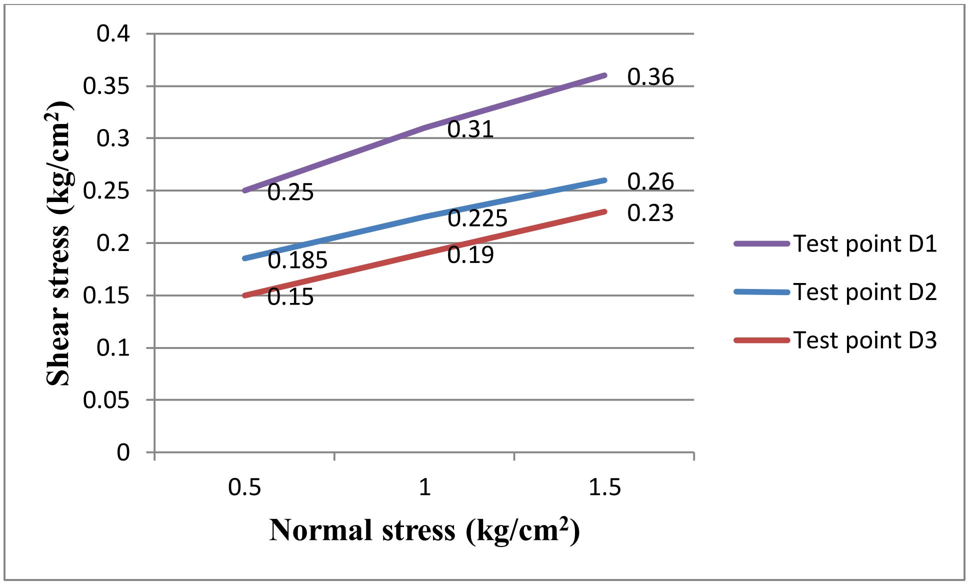

Figure 8(d) – Plot between Normal stress and shear stress for test point D

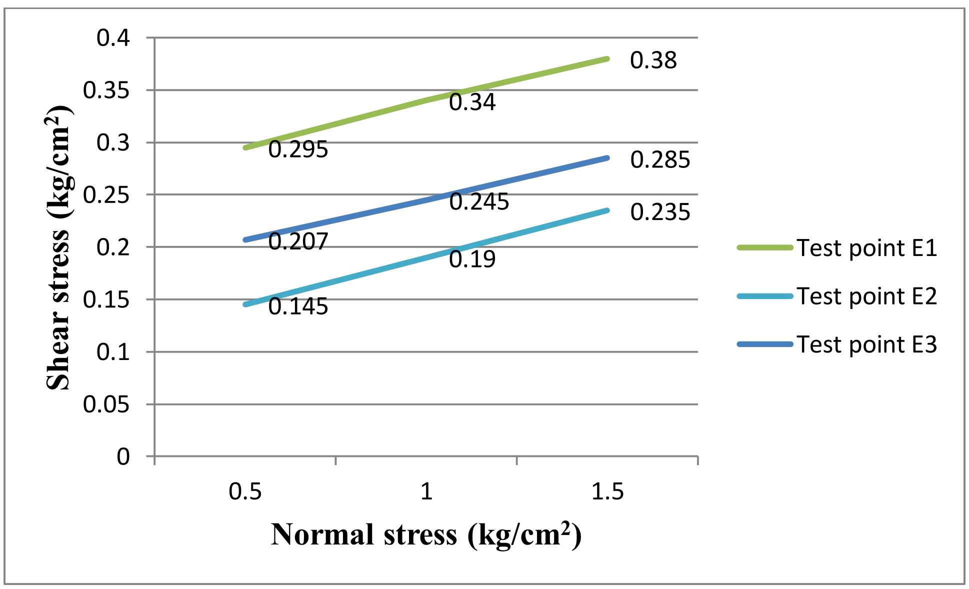

Figure 8(e) – Plot between Normal stress and shear stress for test point E

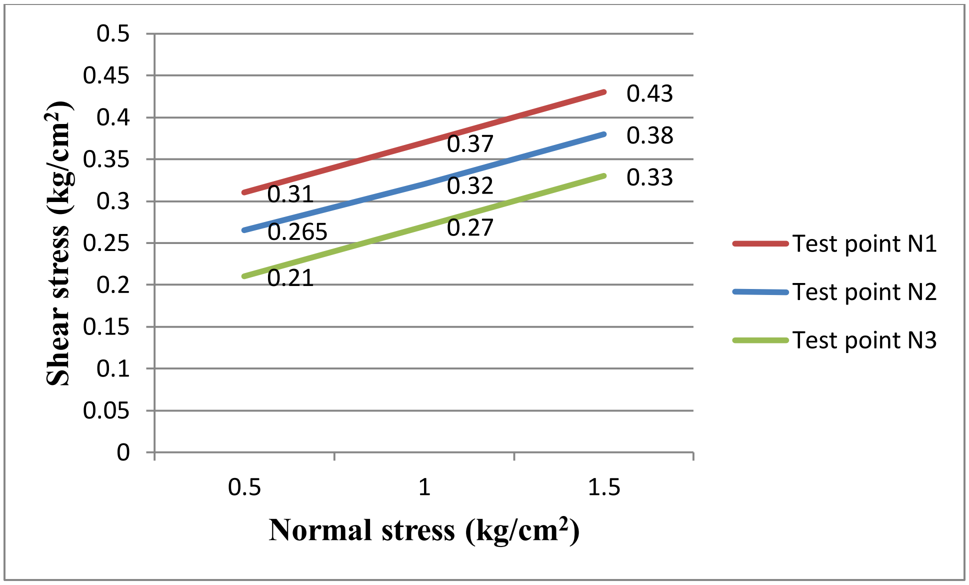

Figure 8(f) – Plot between Normal stress and shear stress for nearby natural soil

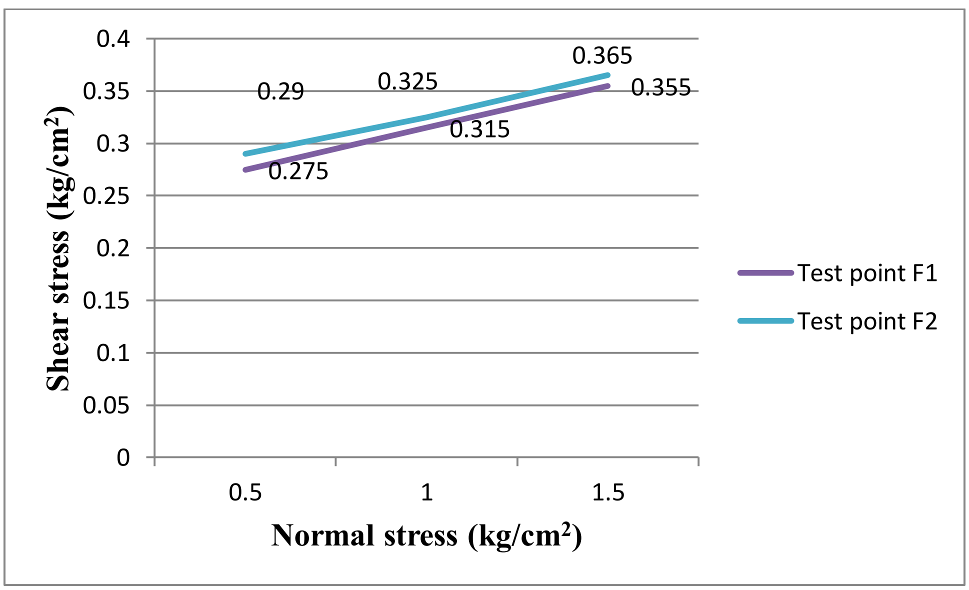

Figure 8(g) – Plot between Normal stress and shear stress for test point F1 and F2

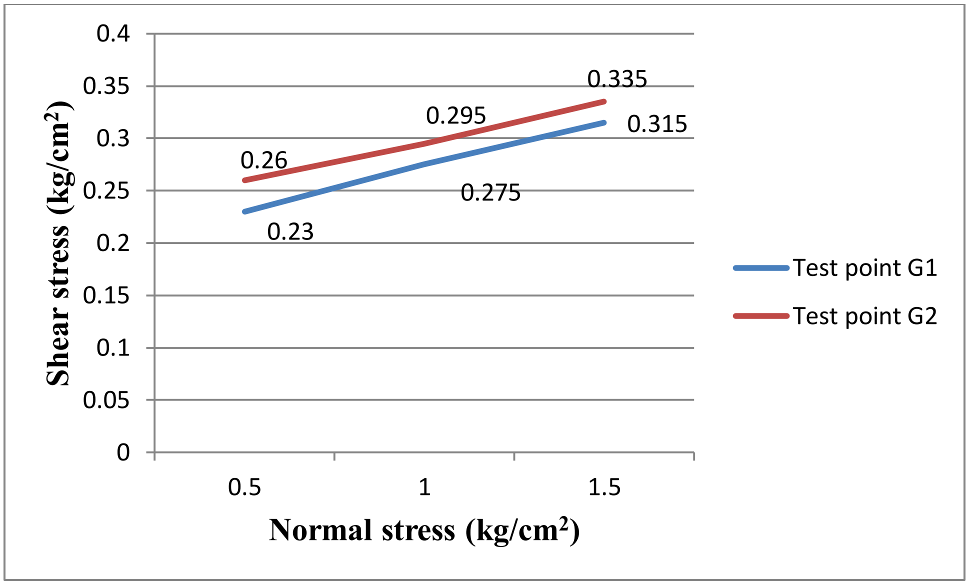

Figure 8(h) – Plot between Normal stress and shear stress for test point G1 and G2

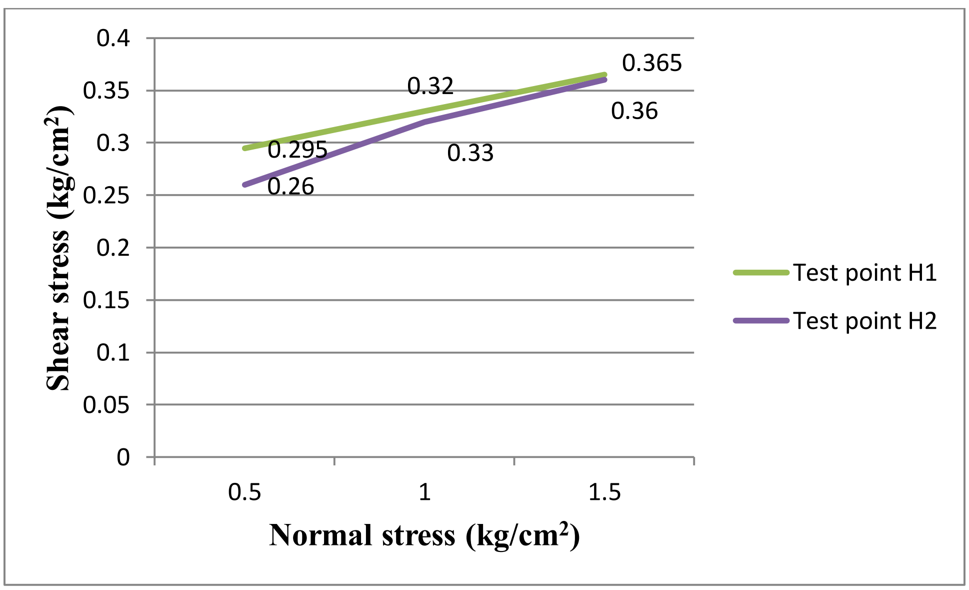

Figure 8(i) – Plot between Normal stress and shear stress for test point H1 and H2

Value of cohesion and angle of internal friction are determined from the above graphs.

SR. NO.	SAMPLE NO.	Cohesion(kg/cm^2) Intercept from graph	Cohesion(kN/m^2)	ϕ angle of internal friction (degrees)
1	A1	0.25	24.51	22
2	A2	0.16	15.69	28
3	A3	0.09	8.83	19
4	B1	0.20	19.61	24
5	B2	0.093	9.12	29
6	B3	0.12	11.77	28
7	C1	0.06	5.88	34
8	C2	0.21	20.59	26
9	C3	0.17	16.67	25
10	D1	0.20	19.61	28
11	D2	0.15	14.71	20
12	D3	0.11	10.79	22
13	E1	0.25	24.52	24
14	E2	0.10	9.81	24
15	E3	0.16	15.69	23
16	N1	0.25	24.51	31
17	N2	0.21	20.59	29
18	N3	0.15	14.71	31
19	F1	0.23	22.55	22
20	F2	0.25	24.51	21
21	G1	0.19	18.63	23
22	G2	0.22	21.57	21
23	H1	0.26	25.49	20
24	H2	0.24	23.53	22

Table 5 – Values of cohesion and angle of internal friction.

3.8 Theoretical analysis

Moisture content, specific gravity, grain size and shear strength parameters are calculated from the above laboratory tests. Values of moisture content lies in range (3.0-7.4) and are used to calculate void ratio. Further unit weight is calculated using void ratio, specific gravity and moisture content. Shear strength parameters C (cohesion) and ϕ (angle of internal friction) are used to calculate bearing capacity. Further settlement is calculated using Marques (2001) model.

3.8.1 Void ratio

Void ratio is calculated using following equation. [17]

$$e = \frac{w}{100} + 0.35 \qquad (4)$$

Where;

e = Void ratio

w = Moisture content (%)

SR. NO.	SAMPLE NO.	Moisture content (w)%	Void ratio (e)
1	A1	5.04	0.40
2	A2	4.66	0.397
3	A3	4.8	0.398
4	B1	3.4	0.384
5	B2	4.6	0.396
6	B3	4.5	0.395
7	C1	5.02	0.40
8	C2	5.6	0.41
9	C3	3.98	0.39
10	D1	3.52	0.385
11	D2	3.6	0.386
12	D3	3	0.38
13	E1	4.2	0.392

14	E2	5.12	0.401
15	E3	4.03	0.390
16	N1	2.67	0.376
17	N2	3.1	0.381
18	N3	5.2	0.402
19	F1	6.9	0.419
20	F2	7.7	0.427
21	G1	6.79	0.418
22	G2	7.6	0.426
23	H1	5.99	0.41
24	H2	7.4	0.424

Table 6- void ratio results

3.8.2 Unit weight of soil

Unit weight is calculated using following equation. [18]

$$\gamma = \left(\frac{1+w}{1+e}\right) \times Gs \times \gamma_w \qquad (5)$$

Where;

w = Moisture content

e = Void ratio

Gs= Specific gravity

γ = Unit weight of soil (kN/m^3)

γ_w = Unit weight of water (kN/m^3)

SR. NO.	SAMPLE NO.	Moisture content (w)%	Void ratio (e)	Specific gravity(G_s)	Unit weight of soil (γ) KN/m^2
1	A1	5.04	0.40	2.01	14.79
2	A2	4.66	0.397	1.98	14.55
3	A3	4.8	0.398	1.9	13.97
4	B1	3.4	0.384	2.25	16.49
5	B2	4.6	0.396	2.1	15.43

6	B3	4.5	0.395	1.72	12.64
7	C1	5.02	0.40	2.2	16.18
8	C2	5.6	0.41	2.3	16.94
9	C3	3.98	0.39	1.78	13.06
10	D1	3.52	0.385	2.32	17.003
11	D2	3.6	0.386	2.12	15.54
12	D3	3	0.38	1.82	13.32
13	E1	4.2	0.392	2.4	17.62
14	E2	5.12	0.401	2.23	16.41
15	E3	4.03	0.390	2.02	14.82
16	N1	2.67	0.376	2.57	18.80
17	N2	3.1	0.381	2.52	18.45
18	N3	5.2	0.402	2.68	19.72
19	F1	6.9	0.419	1.98	14.62
20	F2	7.7	0.427	2.28	16.87
21	G1	6.79	0.418	2.06	15.22
22	G2	7.6	0.426	1.94	14.36
23	H1	5.99	0.41	2.01	14.82
24	H2	7.4	0.424	1.95	14.42

Table 7 - Unit weight of soil for different moisture content and void ratio.

3.8.3 Bearing capacity

Bearing capacity of soil samples is calculated on the basis of Terzaghi's theory published in 1943. Since then various others researchers have worked and improvements have been made. A generalized equation is provided which is used to calculate bearing capacity in this study.

$$q_{ult} = cN_C + qN_q + (0.5 \times B' \times \gamma \times N_\gamma) \quad (6)^{[18]}$$

$$q_{safe} = \frac{q_{ult}}{FOS} \quad (7)^{[18]}$$

Where;

q_{ult} = ultimate bearing capacity (kN/m^2)

q_{safe} = safe bearing capacity (kN/m^2)

FOS = factor of safety (3)

c = cohesion (kN/m^2)

q = unit weight of soil (kN/m^2)*depth (1m) (kN/m^2)

B' = width (1m)

N_c, N_q, N_γ = obtained using ϕ(angle of internal friction) Refer annexure E

γ = unit weight of soil.(kN/m^2)

Sample no.	angle of internal friction ϕ(degrees)	N_c	N_q	N_γ	Cohesion c (kN/m^2)	unit weight (kN/m^3)	q_{ult} (kN/m^2)	q_{safe} (kN/m^2)
A1	22	20.27	9.19	5.09	24.51	14.79	670.3251	223.4417
A2	28	31.61	17.81	13.7	15.69	14.55	854.8029	284.9343
A3	19	16.57	6.7	3.07	8.825	13.97	261.2593	87.08643
B1	24	23.36	11.4	7.08	19.61	16.49	704.4303	234.8101
B2	29	34.24	19.98	16.18	9.119	15.43	745.3903	248.4634
B3	28	31.61	17.81	13.7	11.77	12.64	683.6515	227.8838
C1	34	52.64	36.5	38.04	5.88	16.18	1207.966	402.6552
C2	26	27.09	14.21	9.84	20.59	16.94	881.8671	293.9557
C3	25	25.13	12.72	8.34	16.67	13.06	639.5059	213.1686
D1	28	31.61	17.81	13.7	19.61	17.003	1039.239	346.4131
D2	20	17.69	7.44	3.64	14.71	15.54	404.1084	134.7028
D3	22	20.27	9.19	5.09	10.79	13.32	374.9646	124.9882
E1	24	23.36	11.4	7.08	24.52	17.62	835.895	278.6317
E2	24	23.36	11.4	7.08	9.81	16.41	474.1871	158.0624

E3	23	21.75	10.23	6	15.69	14.82	537.3447	179.1149
N1	31	40.41	25.28	22.65	24.51	18.80	1678.489	559.4965
N2	29	34.24	19.98	16.18	20.59	18.45	1222.9	407.6332
N3	31	40.41	23.28	22.65	14.71	19.72	1276.851	425.617
F1	22	20.27	9.19	5.09	22.55	14.62	628.7527	209.5842
F2	21	18.92	8.26	4.31	24.51	16.87	639.49	213.1633
G1	23	21.75	10.23	6	18.63	15.22	606.5046	202.1682
G2	21	18.92	8.26	4.31	21.57	14.36	557.6212	185.8737
H1	20	17.69	7.44	3.64	25.49	14.82	588.1389	196.0463
H2	22	20.27	9.19	5.09	23.53	14.42	646.2106	215.4035

Table 8 – Bearing capacity of soil.

3.8.4 Calculation of settlement using Marques (2001) model.

Total settlement of municipal solid waste due to surcharge loading is governed by three different mechanism i.e., instantaneous response to load, mechanical creep and biological decomposition.

Marques in year 2001 developed a composite rheological model which account for primary and secondary compression mechanism governed by rheological parameters that also accounts for waste degradation.

The model is represented by equation 7

$$\frac{\Delta H}{H} = C_c \log\left(\frac{\sigma_0 - \Delta\sigma}{\sigma_0}\right) + \Delta\sigma * b * \left(1 - e^{-ct`}\right) + E_{DG} * \left(1 - e^{-dt``}\right)$$ [12]

(7)

Where;

ΔH = settlement

H = Initial height of waste

C_c =primary compression ratio (0.106)

$\Delta\sigma$ =surcharge load.

σ_o =soil Overburden load (unit weight x depth)

c =secondary mechanical compression rate (1.79×10^{-3})

Edg =total compression due to waste degradation (0.159)

D =secondary biological compression rate (1.14×10^{-3})

t` =time elapsed since loading application

t`` =time elapsed since waste disposal

b =coefficient of secondary mechanical compression (5.72×10^{-4})

Total long settlement calculation due to surcharge loading is calculated using above equation and recorded in tabular form as follows.

SR.NO.	TIME(years)	ΔH at 1m depth(m)	ΔH at 2m depth(m)	ΔH at 3m depth (m)	ΔH at 5m depth (m)	ΔH at 8m depth (m)
1	1	0.807891	0.527632	0.411828	0.282475	0.194723
2	2	0.811122	0.530863	0.41506	0.285707	0.197955
3	3	0.81435	0.534091	0.418288	0.288935	0.201183
4	4	0.817574	0.537315	0.421512	0.292158	0.204407
5	5	0.820794	0.540535	0.424732	0.295378	0.207626
6	10	0.836833	0.556574	0.44077	0.311417	0.223665
7	15	0.852772	0.572513	0.456709	0.327356	0.239604
8	20	0.868612	0.588353	0.472549	0.343196	0.255444

Table 9- Variation of settlement with depth and time.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

A major important thing in engineering judgment is the confidence which is placed on the possibility of measured properties of material of the fact of past events resulting in failure which possibly may explain the likely order of same circumstances. The abandoned landfill site soil investigation gives un-satisfactory results for any hard top use. This abandoned landfill site soil shows a little variation in geotechnical properties to the nearby natural soil.

4.2 Moisture content test

The determination of water content of soil is one of the major engineering activity that is undertaken before constructing a structure. Water is one of the major driving component that governs the engineering properties of any soil sample. The presence of water in the soil capillaries affects the engineering properties of soil. The moisture content of the MSW soil samples show variation with depth ranging from 3.0 % to 7.7 %. Figure 9 shows the graphical representation of the results of moisture content (%) varying with depth at different test.

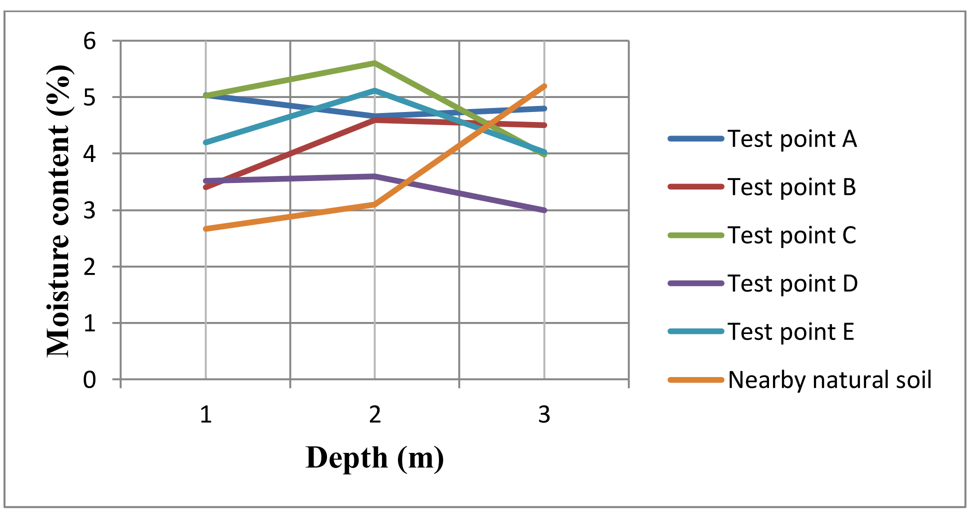

Figure 9(a) - Plot of Moisture content with depth for test points A,B,C,D,E and nearby natural soil.

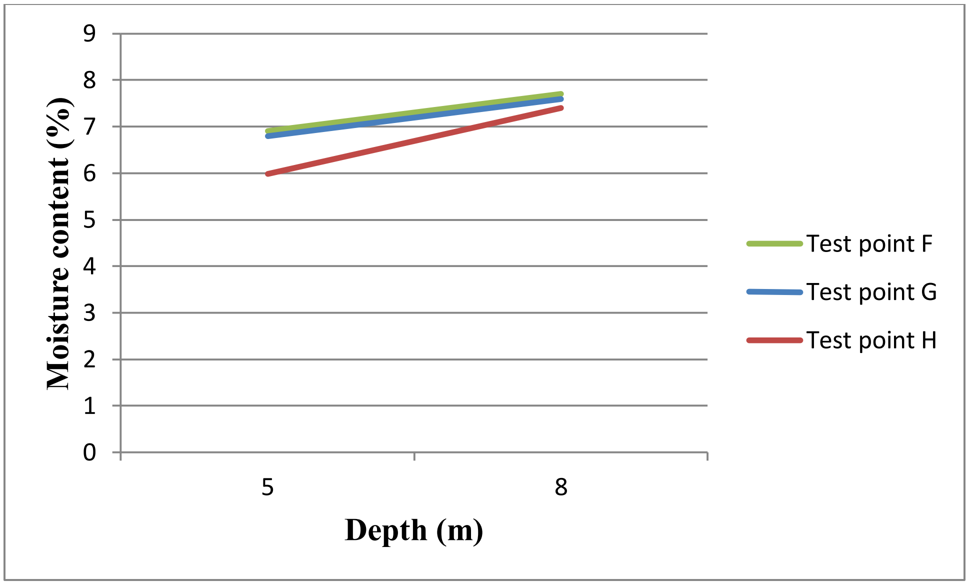

Figure 9(b) - Plot of Moisture content with depth for test points F, G, and H.

4.3 Specific gravity test results

The specific gravity of the soil samples was determined using pycnometer method. The specific gravity results falls in the range of organic soil (1.72-2.23) which is correctly determined as the MSW site soil is organic in nature.

4.4 Grain size analysis results

Grain size of the MSW site soil was determined using sieve analysis.

Results shows that the grain size of particles are larger than expected for municipal solid waste site soil. This may be because the site under study was an un-engineered site where the organic soil of MSW was mixed with soil and rocks for cover on daily basis. Furthermore the particles may have strong intermolecular forces and hence error may be caused in sieve analysis results.

4.5 Variation of Safe bearing capacity of soil with depth for different test points.

Safe bearing capacity of MSW site soil shows irregularities with different depths, the bearing capacity is varying from (87kN/m^2- 402 kN/m^2). This huge variation can be explained due to presence of the mixed martrix of soil and MSW. Figure 10 shows the plot of varying bearing capacity with depths for different test points.

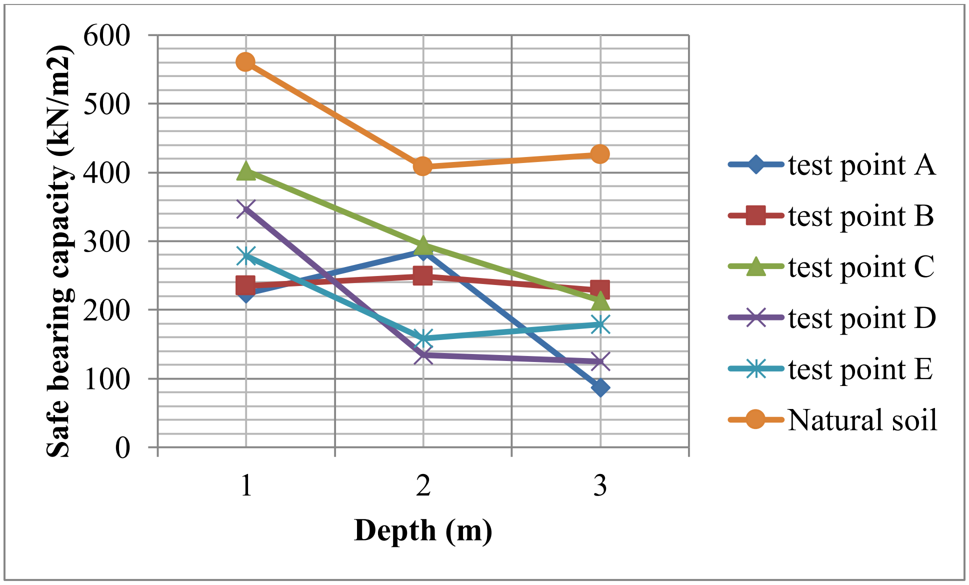

Figure 10(a)-Plot showing varying bearing capacity with depths for different test points.

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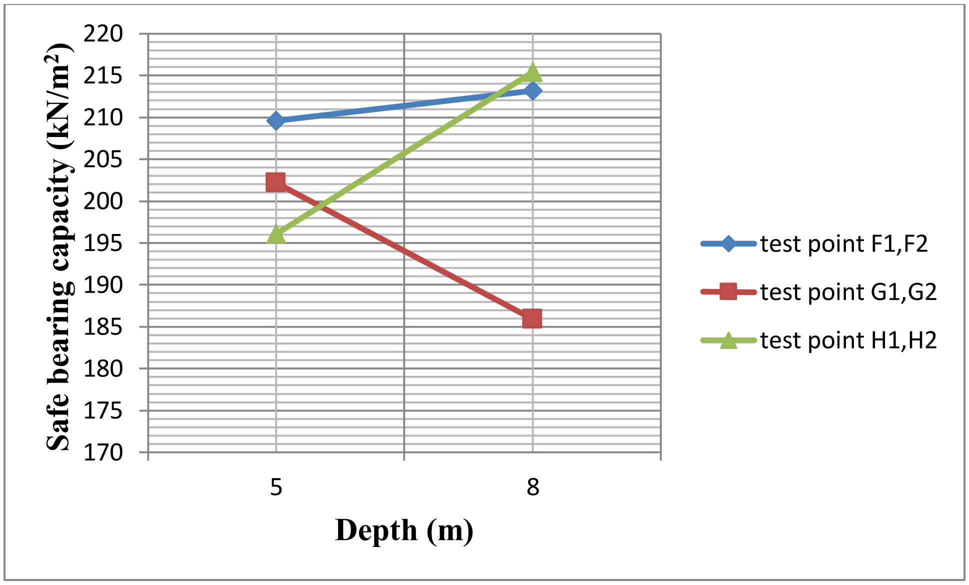

Figure 10(b) - Plot showing varying bearing capacity with depths for Different test points

4.6 Settlement v/s time plot for different depths.

Settlement of MSW site was calculated using Marques (2001) model.

Following graphs shows settlement at different depths at different time interval.

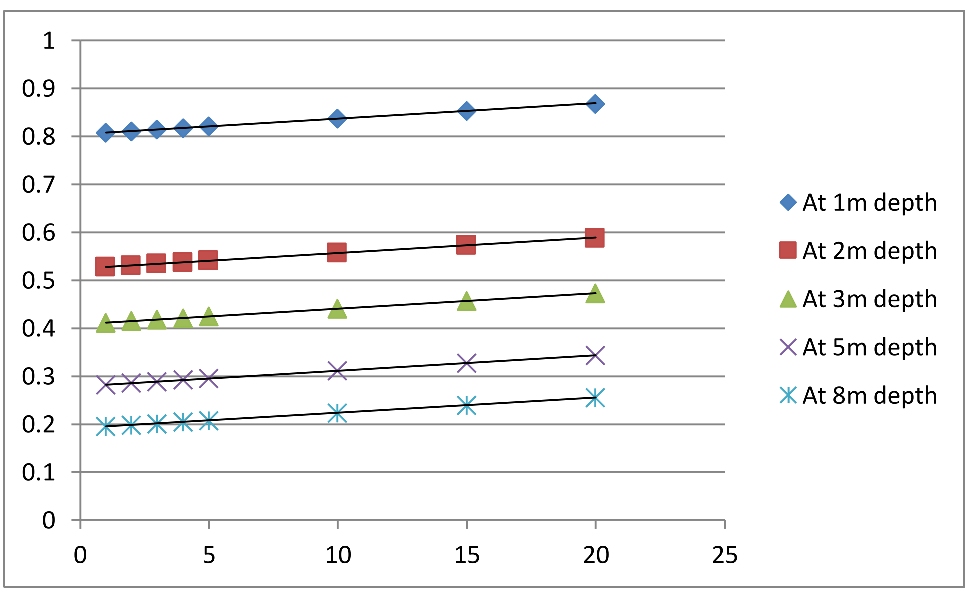

Figure 11- Plot showing settlement at different depths for different time intervals

CHAPTER 5
CONCLUSIONS

Based on the laboratory tests and theoretical analysis following conclusion can be made.

1. The geotechnical properties of MSW site soil shows irregular variation at different test points and hence detailed geotechnical investigation is required for accessing the exact geotechnical capabilities of MSW site soil. The soil is organic in nature concluded from the specific gravity values which are ranging between 1.72 and 2.23. Also the values of shear strength parameters shows variation for different test points at different depths, this can be explained as the presence of weak zones and 'reinforced earth scenarios' usually due to mix matrix of soil and non-soil materials.

2. Settlement calculations shows that the settlement values for the site under investigation are exceeding the maximum allowable settlement limits for any RCC structure and hence the site is considered as unsuitable for any hard top usage. This Abandoned solid waste site can be used for soft top use like Nature Park etc. Settlement due to waste degradation is considered as negligible after 20 yr time and hence further studies can be done after the settlement process is complete.

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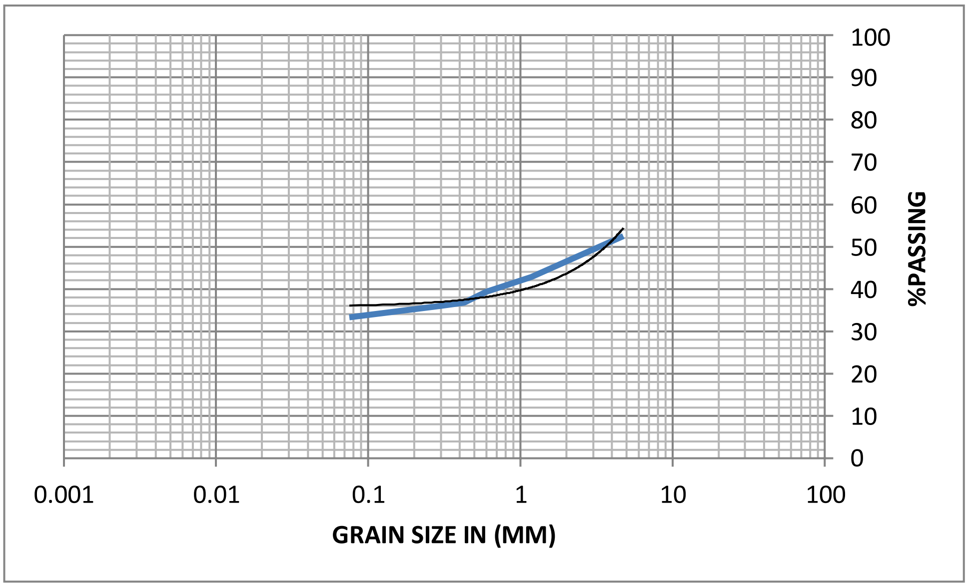
ANNEXURE

ANNEXURE A

Annexure A shows the test values of Sieve Analysis for different samples.

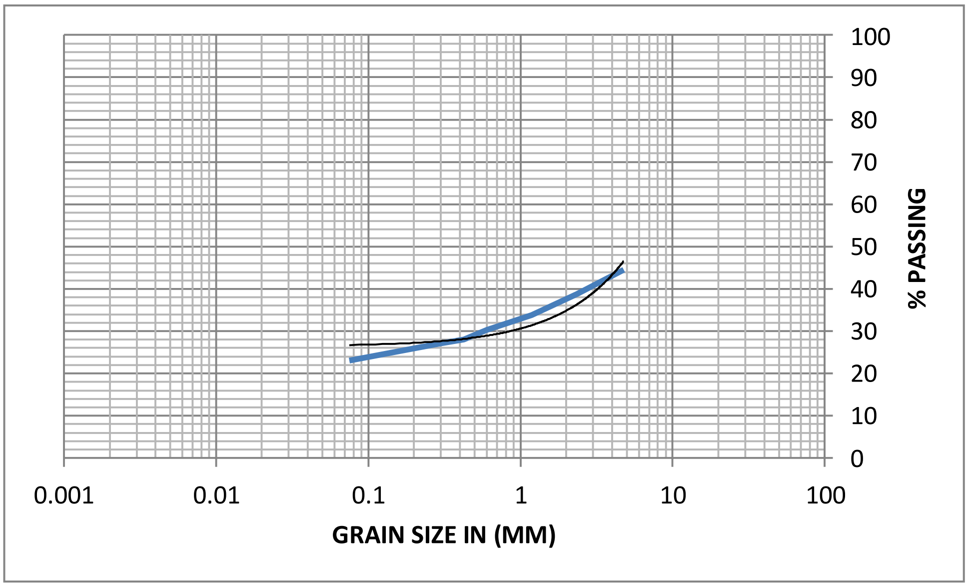
Sample A-1

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	237.5	52.5
2	2.36	24.5	47.6
3	1.18	23.5	42.9
4	0.600	17.5	39.4
5	0.425	13.0	36.8
6	0.300	4.0	36.0
7	0.075	13.5	33.3



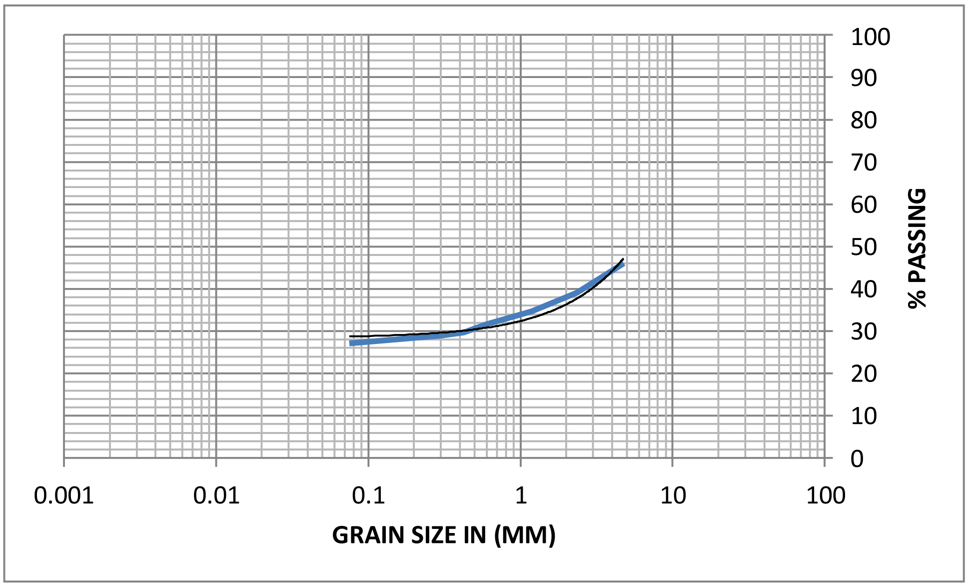
Sample A-2

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	277	44.6
2	2.36	29	38.8
3	1.18	25	33.8
4	0.600	17.5	30.3
5	0.425	11.5	28
6	0.300	4.0	27.2
7	0.075	21.0	23.0



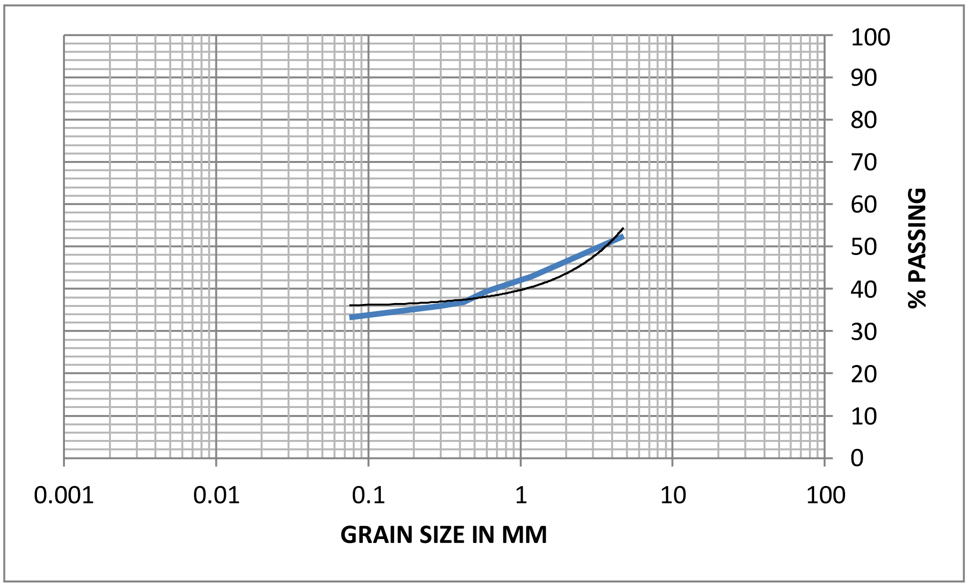
Sample A-3

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	269.5	46.1
2	2.36	35	39.1
3	1.18	22	34.7
4	0.600	15.5	31.6
5	0.425	9.5	29.7
6	0.300	3.5	29.0
7	0.075	8.5	27.2



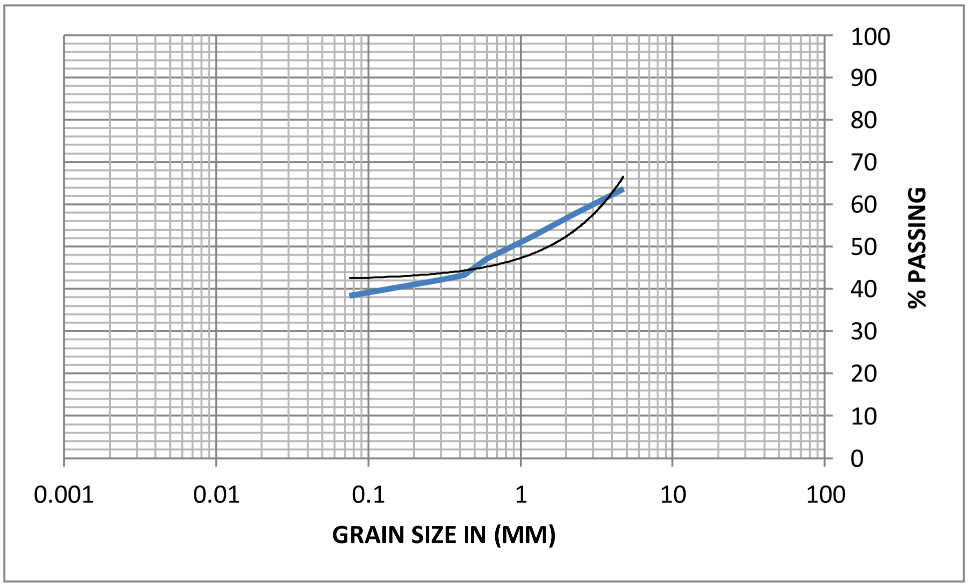
Sample B-1

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	237.5	52.5
2	2.36	24.5	47.6
3	1.18	23.5	42.9
4	0.600	17.5	39.4
5	0.425	13.0	36.8
6	0.300	4.0	36.0
7	0.075	13.5	33.3



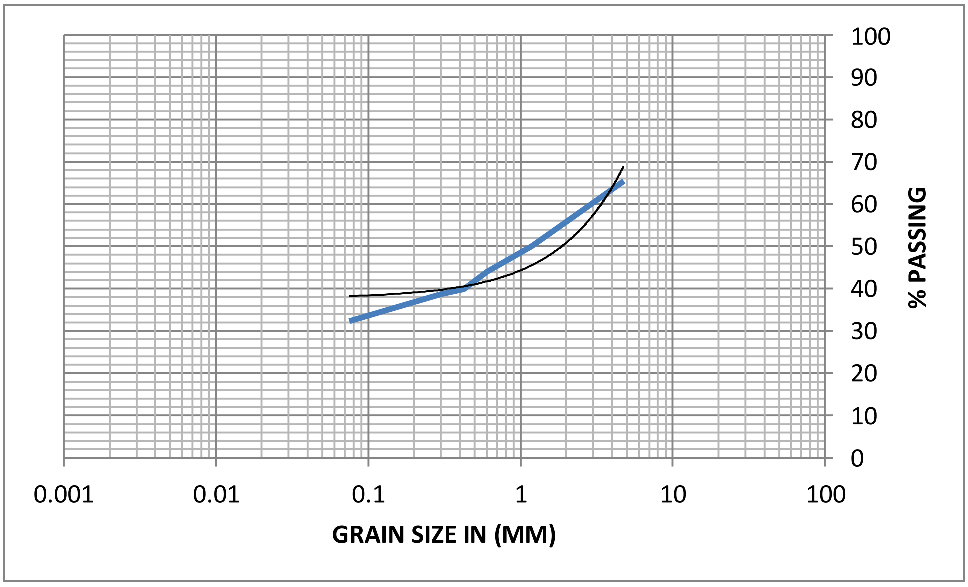
Sample B-2

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	181.5	63.7
2	2.36	28.5	58.0
3	1.18	28.5	52.3
4	0.600	26	47.1
5	0.425	19.5	43.2
6	0.300	5.5	42.1
7	0.075	18.5	38.4



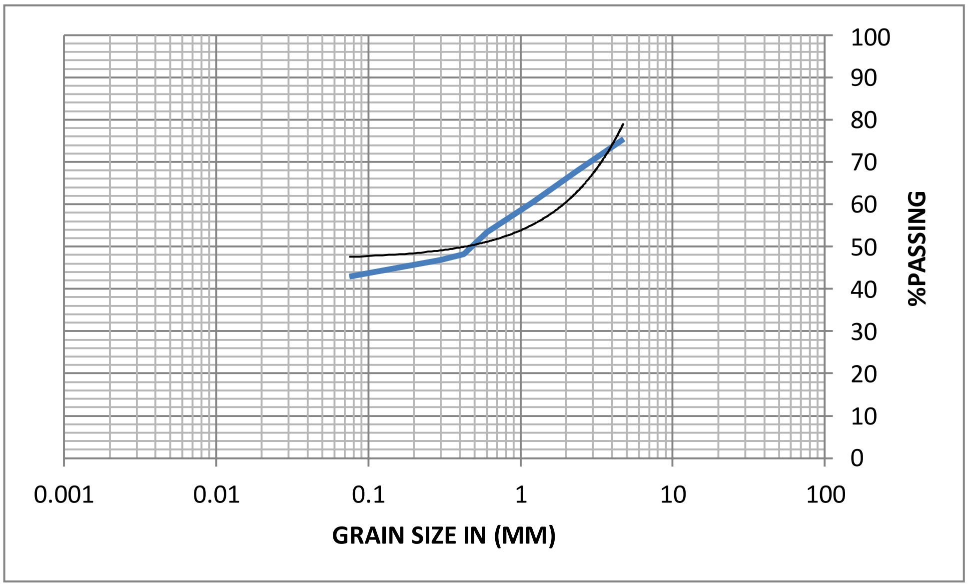
Sample B-3

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	172.5	65.5
2	2.36	39.5	57.6
3	1.18	38.0	50
4	0.600	30.5	43.9
5	0.425	20	39.9
6	0.300	6.5	38.6
7	0.075	31.5	32.3



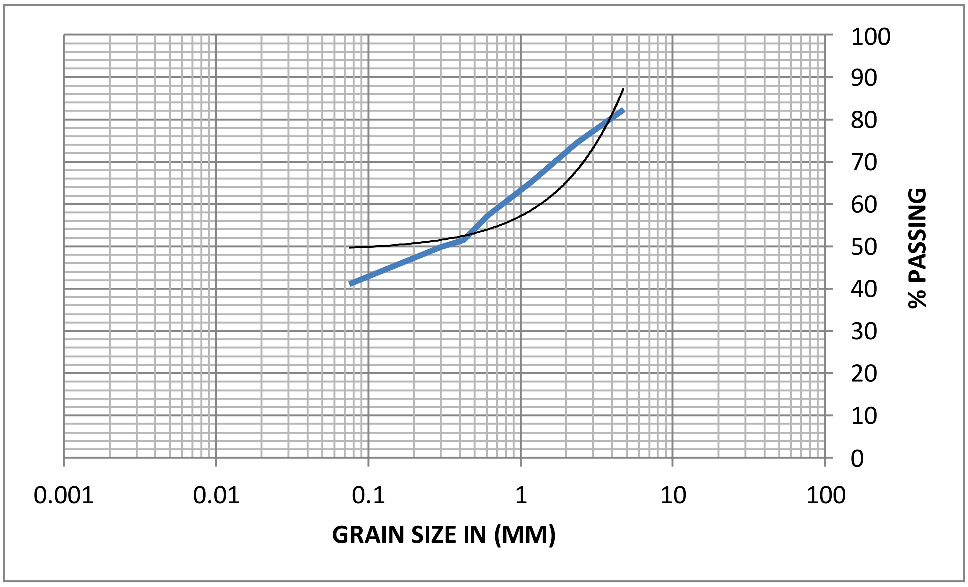
Sample C-1

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	123	75.4
2	2.36	37.5	67.9
3	1.18	38.0	60.3
4	0.600	35.0	53.3
5	0.425	25.5	48.2
6	0.300	7.0	46.8
7	0.075	19.5	42.9



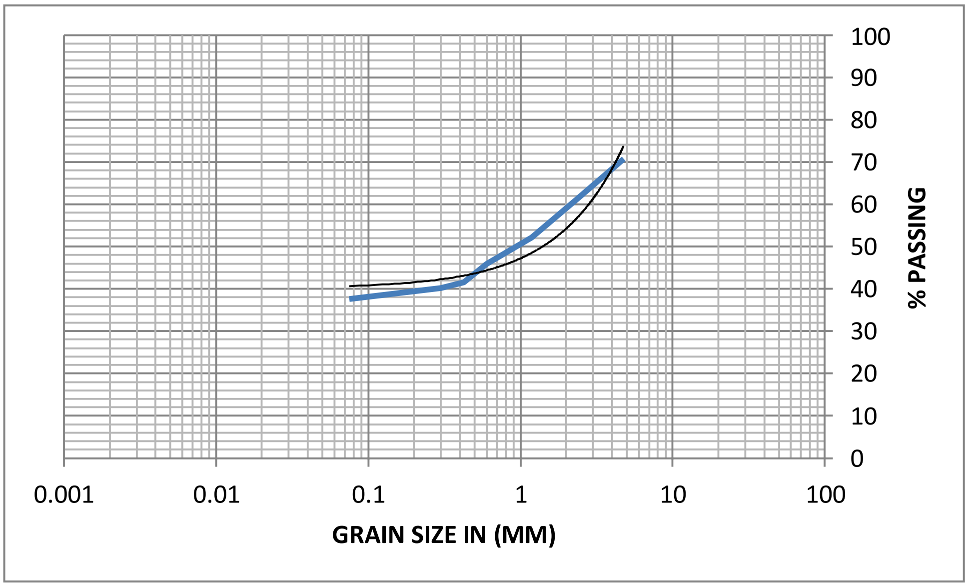
Sample C-2

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	88	82.4
2	2.36	39.5	74.5
3	1.18	46.5	65.2
4	0.600	40.5	57.1
5	0.425	28	51.5
6	0.300	8.5	49.8
7	0.075	43.5 `	41.1



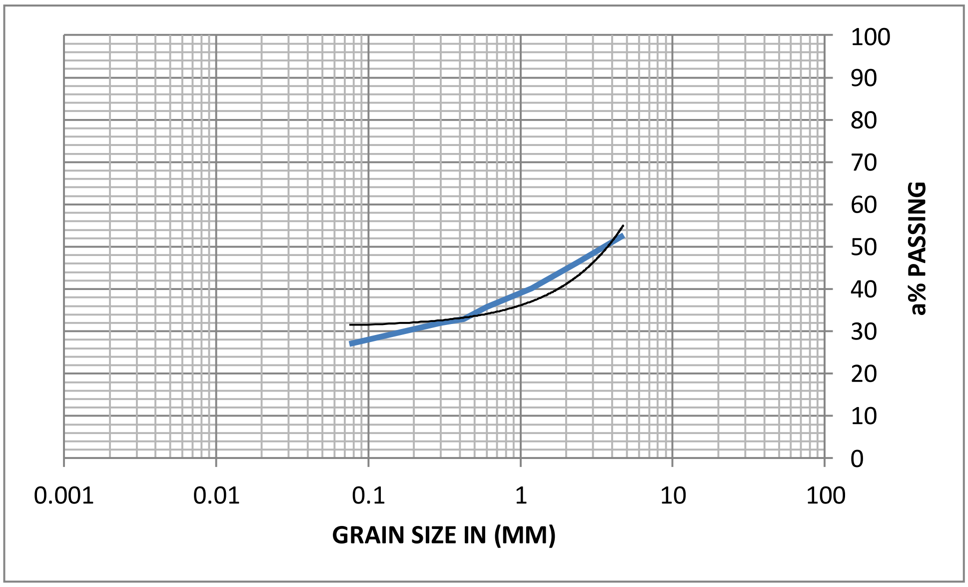
Sample C-3

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	146.5	70.7
2	2.36	47.5	61.2
3	1.18	45	52.2
4	0.600	31.0	46.0
5	0.425	22.5	41.5
6	0.300	6.5	40.2
7	0.075	13	37.6



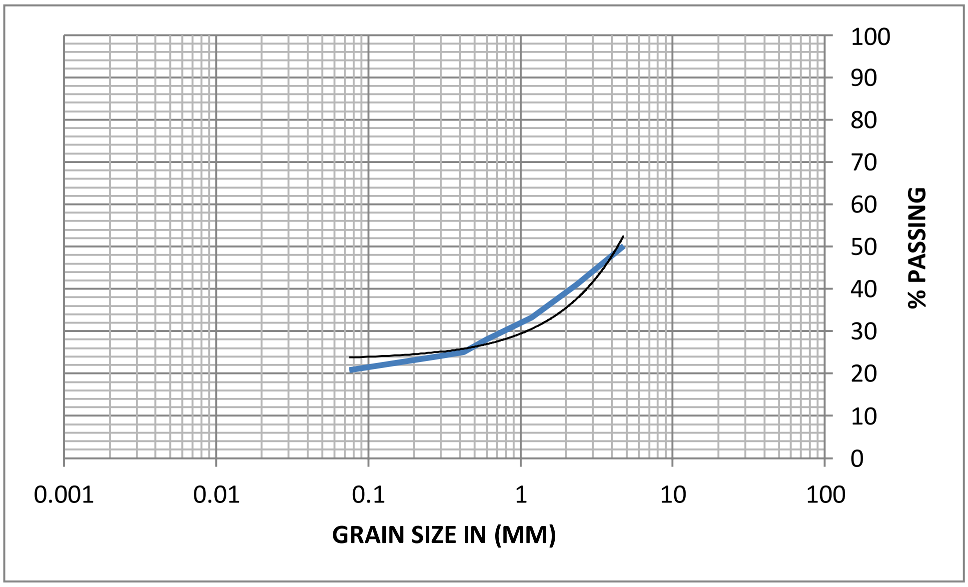
Sample D-1

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	236.5	52.7
2	2.36	32.5	46.2
3	1.18	30.5	40.1
4	0.600	21.5	35.8
5	0.425	14.5	32.9
6	0.300	4.5	32.0
7	0.075	25.0	27.0



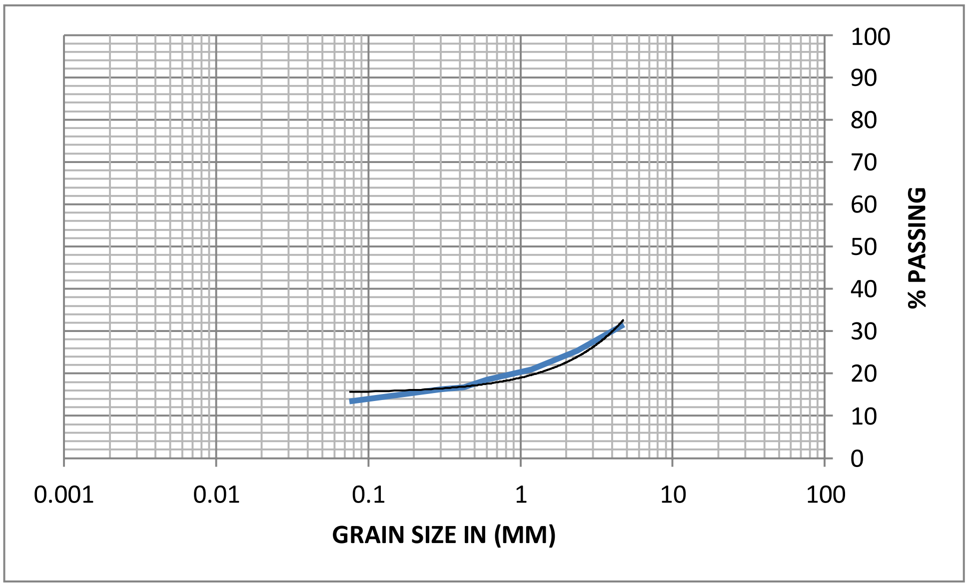
Sample D-2

S. No.	`IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	249	50.2
2	2.36	45.5	41.1
3	1.18	39.5	33.2
4	0.600	26.0	28.0
5	0.425	14.5	25.1
6	0.300	4.5	24.2
7	0.075	17.0	20.8



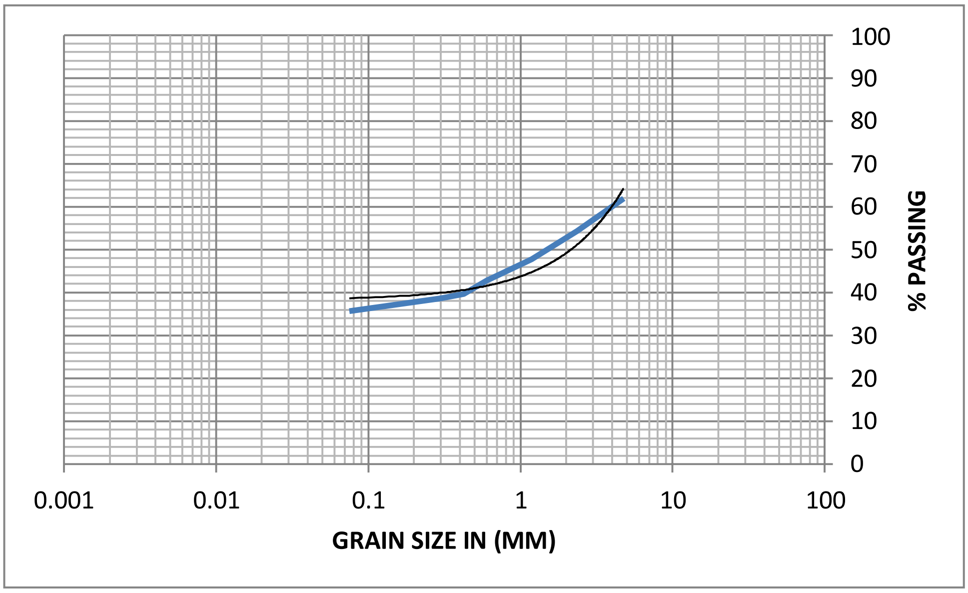
Sample D-3

S. No.`	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	312.5	37.5
2	2.36	40.5	29.4
3	1.18	27.0	24.0
4	0.600	17.5	20.5
5	0.425	18.5	16.8
6	0.300	3.0	16.2
7	0.075	14.0	13.4



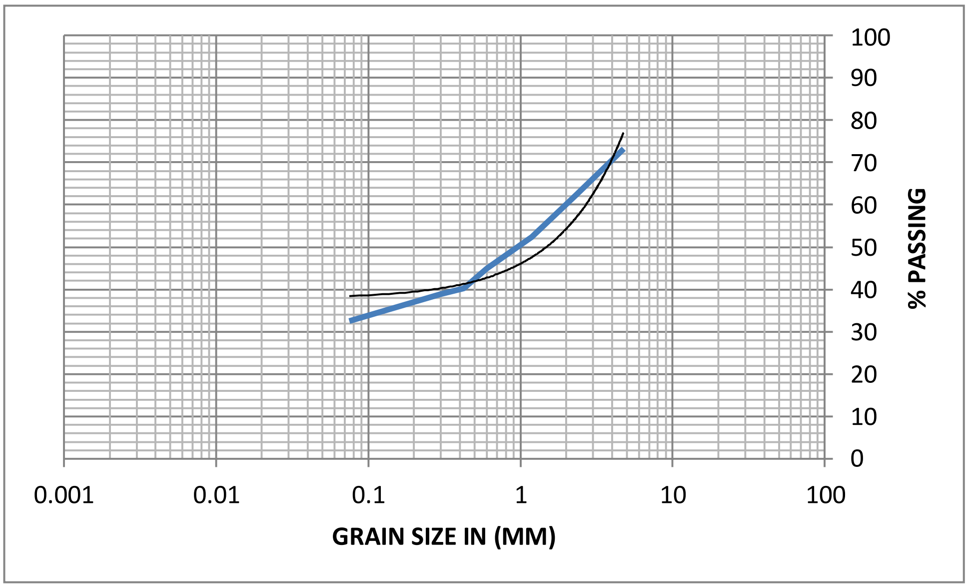
Sample E-1

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	190.5	61.9
2	2.36	38.0	54.3
3	1.18	32.5	47.8
4	0.600	25.0	42.8
5	0.425	15.5	39.7
6	0.300	5.5	38.6
7	0.075	14.5	35.7



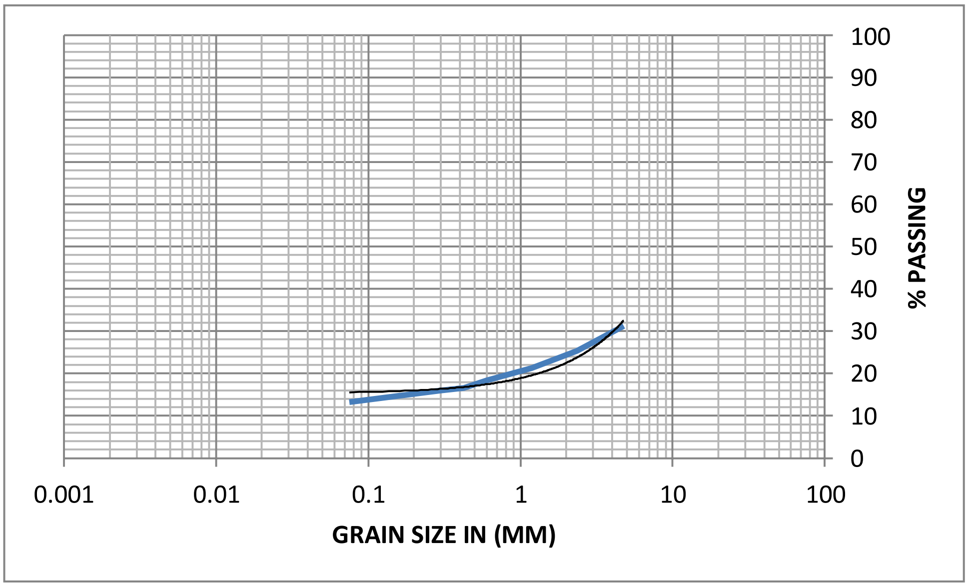
Sample E-2

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	134	73.2
2	2.36	53.5	62.5
3	1.18	51.0	52.3
4	0.600	37.0	44.9
5	0.425	23	40.3
6	0.300	7.0	38.9
7	0.075	32.0	32.5



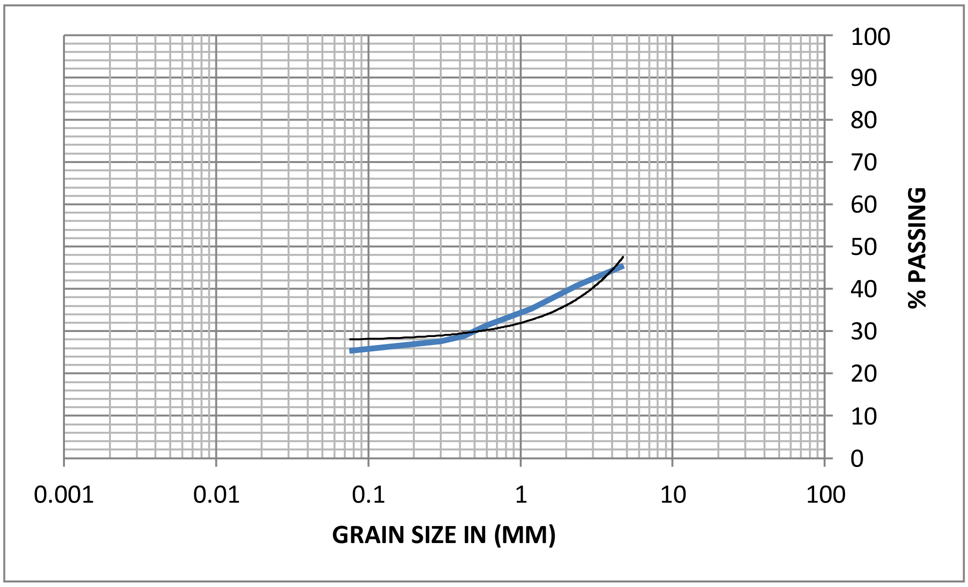
Sample E-3

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	344	31.2
2	2.36	29	25.4
3	1.18	21	21.2
4	0.600	14	18.4
5	0.425	9.0	16.6
6	0.300	3.0	16.0
7	0.075	14.0	13.2



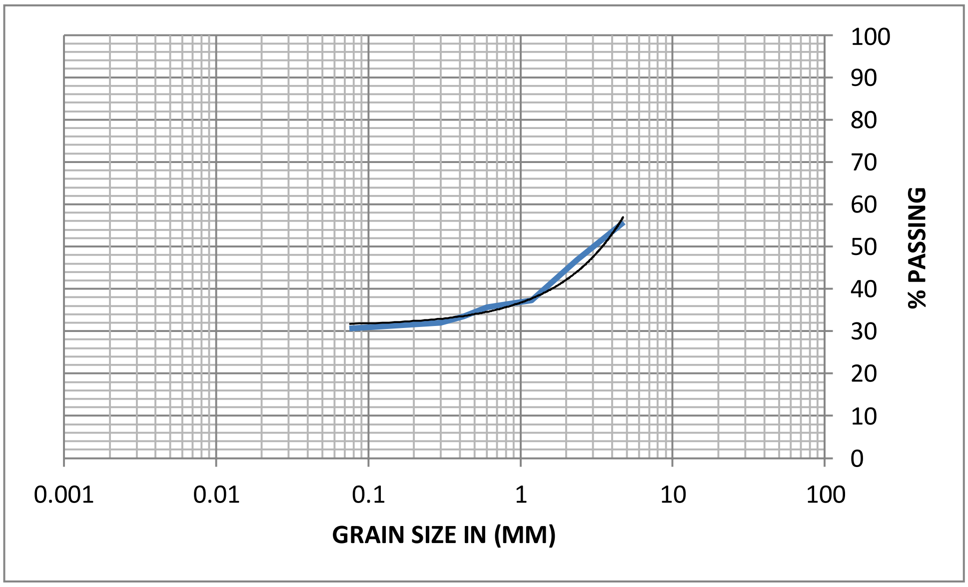
Sample N-1

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	273	45.4
2	2.36	23	40.8
3	1.18	27	35.4
4	0.600	20	31.4
5	0.425	13	28.8
6	0.300	6.0	27.6
7	0.075	11.0	25.4



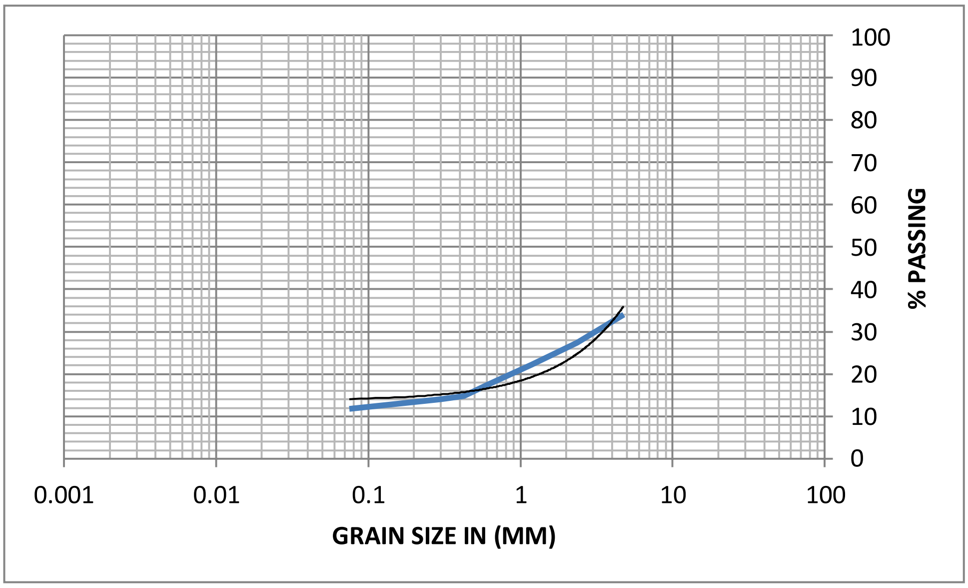
Sample N-2

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	221.5	55.7
2	2.36	44	46.9
3	1.18	48	37.3
4	0.600	8.0	35.7
5	0.425	11	33.5
6	0.300	7.5	32
7	0.075	7.0	30.6



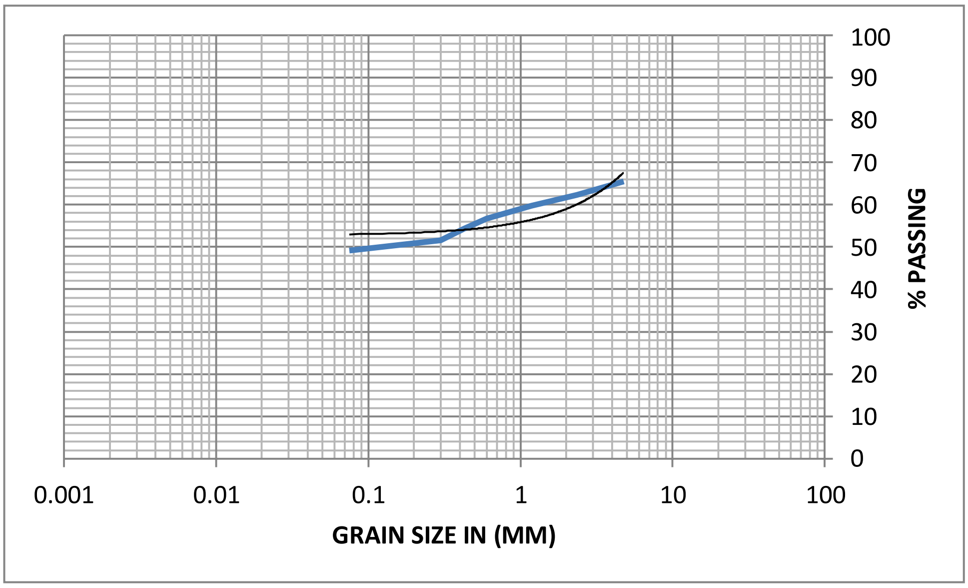
Sample N-3

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	330	34
2	2.36	33	27.4
3	1.18	26	22.2
4	0.600	24	17.4
5	0.425	13	14.8
6	0.300	4.0	14.0
7	0.075	11.0	11.8



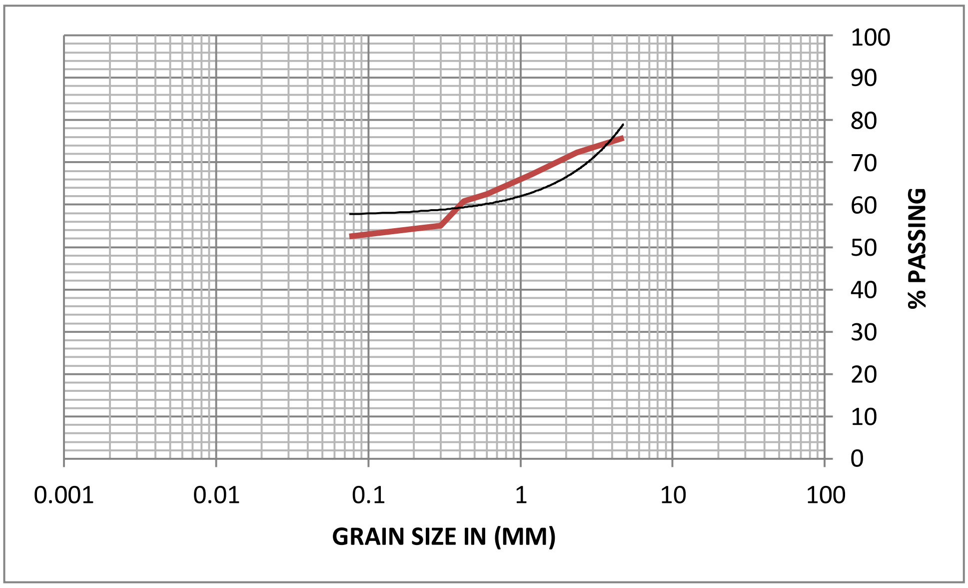
Sample F-1

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	172.5	65.5
2	2.36	16.0	62.3
3	1.18	12.5	59.8
4	0.600	15.5	56.7
5	0.425	12.0	54.3
6	0.300	13.5	51.6
7	0.075	12.0	49.2



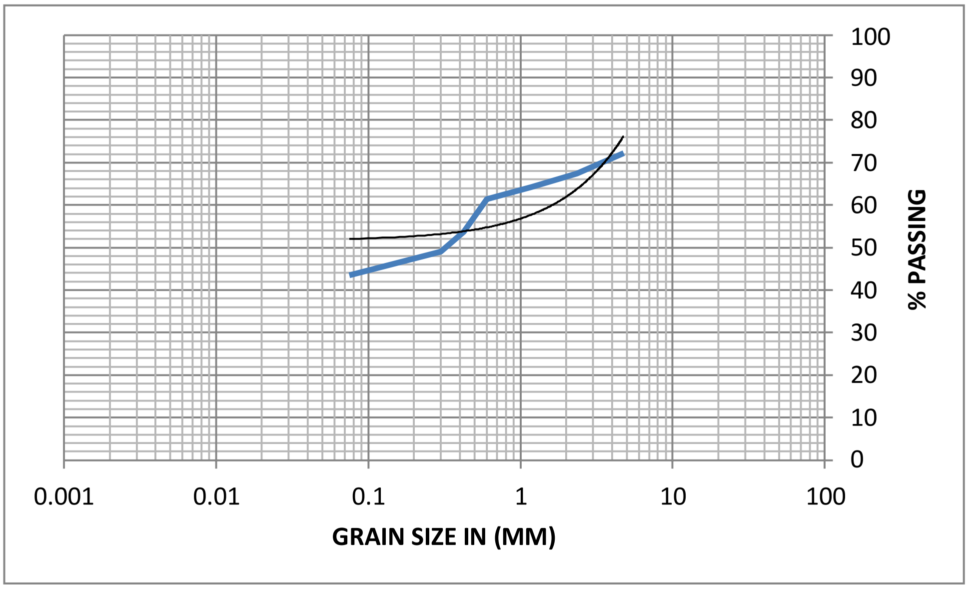
Sample F-2

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	121	75.8
2	2.36	17.5	72.3
3	1.18	25.5	67.2
4	0.600	23.5	62.5
5	0.425	8.0	60.9
6	0.300	29.0	55.1
7	0.075	13.0	52.5



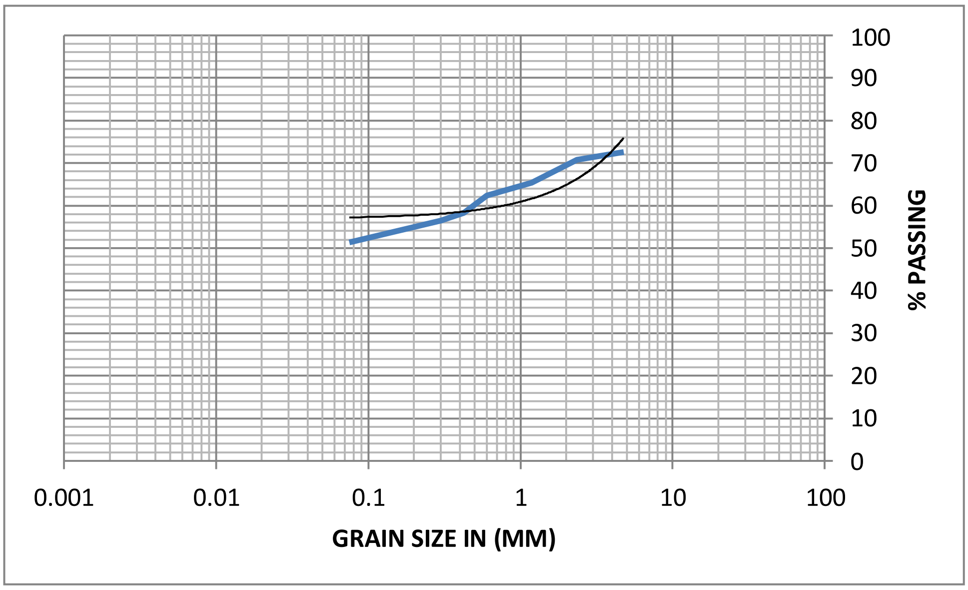
Sample G-1

S. No.	IS sieve (mm)	Wt. retained (gm)	% Passing
1	4.75	138.5	72.3
2	2.36	24.5	67.4
3	1.18	15.3	64.3
4	0.600	14.7	61.4
5	0.425	38.5	53.7
6	0.300	23.5	49.0
7	0.075	28.0	43.4



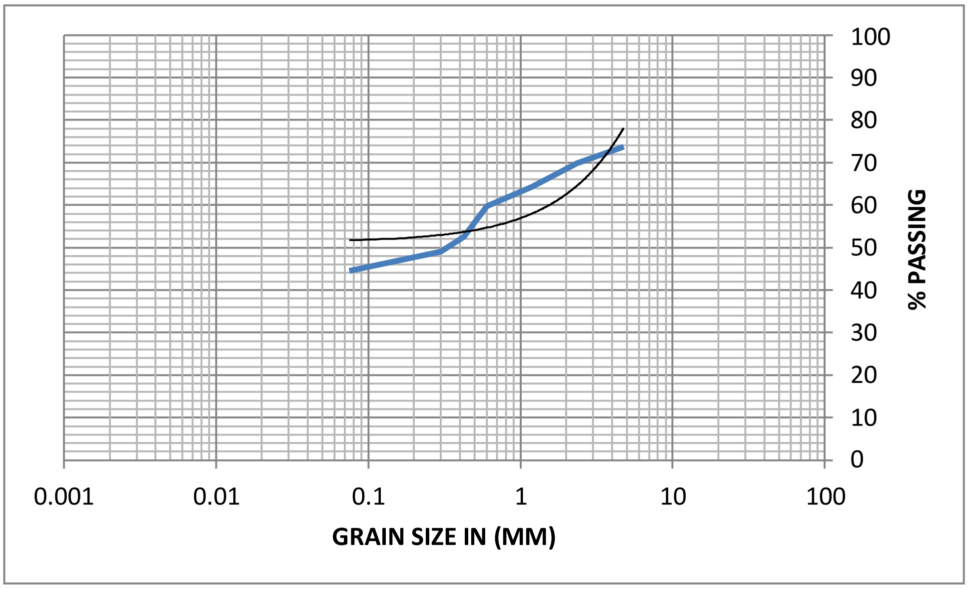
Sample G-2

S. No.	**IS sieve mm**	**Wt. retained (gm)**	**% Passing**
1	4.75	137.5	72.5
2	2.36	8.5	70.8
3	1.18	27.5	65.3
4	0.600	14.5	62.4
5	0.425	21	58.2
6	0.300	9.0	56.4
7	0.075	25.5	51.3



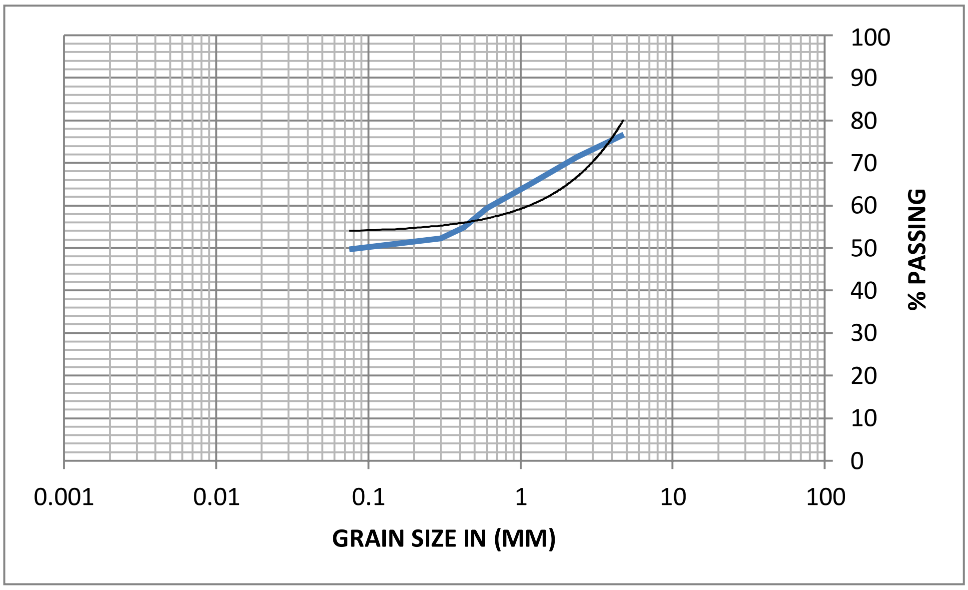
Sample H-1

S. No.	IS sieve mm	Wt. retained (gm)	% Passing
1	4.75	131.5	73.7
2	2.36	19.5	69.8
3	1.18	27.5	64.3
4	0.600	23.0	59.7
5	0.425	36.0	52.5
6	0.300	17.0	49.1
7	0.075	23.0	44.5



Sample H-2

S. No.	IS sieve mm	Wt. retained (gm)	% Passing
1	4.75	117	76.6
2	2.36	26	71.4
3	1.18	31	65.2
4	0.600	29.5	59.3
5	0.425	22.5	54.8
6	0.300	13	52.2
7	0.075	12.5	49.7



ANNEXURE B

Annexure B shows the test values of Moisture Content using oven dry method for different samples.

Sample A-1

W1(gm)	40
W2(gm)	290
W3(gm)	278

Sample A-2

W1(gm)	40
W2(gm)	287
W3(gm)	276

Sample A-3

W1(gm)	40
W2(gm)	280
W3(gm)	269

Sample B-1

W1(gm)	40
W2(gm)	250
W3(gm)	243

Sample B-2

W1(gm)	40
W2(gm)	255
W3(gm)	245.5

Sample B-3

W1(gm)	40
W2(gm)	271
W3(gm)	261

Sample C-1

W1(gm)	40
W2(gm)	270
W3(gm)	259

Sample C-2

W1(gm)	40
W2(gm)	285
W3(gm)	272

Sample C-3

W1(gm)	40
W2(gm)	275
W3(gm)	266

Sample D-1

W1(gm)	40
W2(gm)	260
W3(gm)	252.5

Sample D-2

W1(gm)	40
W2(gm)	270
W3(gm)	262

Sample D-3

W1(gm)	40
W2(gm)	280
W3(gm)	273

Sample E-1

W1(gm)	40
W2(gm)	285
W3(gm)	275

Sample E-2

W1(gm)	40
W2(gm)	286
W3(gm)	274

Sample E-3

W1(gm)	40
W2(gm)	272
W3(gm)	263

Sample N-1

W1(gm)	40
W2(gm)	270
W3(gm)	264

Sample N-2

W1(gm)	40
W2(gm)	267
W3(gm)	260

Sample N-3

W1(gm)	40
W2(gm)	282
W3(gm)	270

Sample F-1

W1(gm)	48
W2(gm)	295
W3(gm)	279

Sample F-2

W1(gm)	49
W2(gm)	298
W3(gm)	280

Sample G-1

W1(gm)	48
W2(gm)	284
W3(gm)	269

Sample G-2

W1(gm)	49
W2(gm)	288
W3(gm)	271

Sample H-1

W1(gm)	49
W2(gm)	279
W3(gm)	266

Sample H-2

W1(gm)	49
W2(gm)	293
W3(gm)	276

ANNEXURE C

Annexure C shows the test values of Specific Gravity test using Pycnometer method for different samples.

Sample A-1

W1(gm)	540
W2(gm)	788
W3(gm)	1394.6
W4(gm)	1270

Sample A-2

W1(gm)	540
W2(gm)	792
W3(gm)	1395.7
W4(gm)	1271

Sample A-3

W1(gm)	540
W2(gm)	780
W3(gm)	1383.6
W4(gm)	1270

Sample B-1

W1(gm)	540
W2(gm)	760
W3(gm)	1392.2
W4(gm)	1270

Sample B-2

W1(gm)	540
W2(gm)	772
W3(gm)	1391.5
W4(gm)	1270

Sample B-3

W1(gm)	540
W2(gm)	800
W3(gm)	1378.8
W4(gm)	1270

Sample C-1

W1(gm)	540
W2(gm)	782
W3(gm)	1402
W4(gm)	1270

Sample C-2

W1(gm)	540
W2(gm)	784
W3(gm)	1407.9
W4(gm)	1270

Sample C-3

W1(gm)	540
W2(gm)	794
W3(gm)	1381.3
W4(gm)	1270

Sample D-1

W1(gm)	540
W2(gm)	745
W3(gm)	1386.6
W4(gm)	1270

Sample D-2

W1(gm)	540
W2(gm)	764
W3(gm)	1388.3
W4(gm)	1270

Sample D-3

W1(gm)	540
W2(gm)	778
W3(gm)	1377.2
W4(gm)	1270

Sample E-1

W1(gm)	540
W2(gm)	789
W3(gm)	1415.2
W4(gm)	1270

Sample E-2

W1(gm)	540
W2(gm)	762
W3(gm)	1392.4
W4(gm)	1270

Sample E-3

W1(gm)	540
W2(gm)	766
W3(gm)	1384.1
W4(gm)	1270

Sample N-1

W1(gm)	540
W2(gm)	789
W3(gm)	1422.1
W4(gm)	1270

Sample N-2

W1(gm)	540
W2(gm)	774
W3(gm)	1411.1
W4(gm)	1270

Sample N-3

W1(gm)	540
W2(gm)	793
W3(gm)	1428.5
W4(gm)	1270

Sample F-1

W1(gm)	540
W2(gm)	793
W3(gm)	1395.2
W4(gm)	1270

Sample F-2

W1(gm)	540
W2(gm)	796
W3(gm)	1415.2
W4(gm)	1271

Sample G-1

W1(gm)	540
W2(gm)	781
W3(gm)	1394.1
W4(gm)	1270

Sample G-2

W1(gm)	540
W2(gm)	779
W3(gm)	1386.1
W4(gm)	1270

Sample H-1

W1(gm)	541
W2(gm)	774
W3(gm)	1387.1
W4(gm)	1270

Sample H-2

W1(gm)	540
W2(gm)	783
W3(gm)	1388.5
W4(gm)	1270

ANNEXURE D

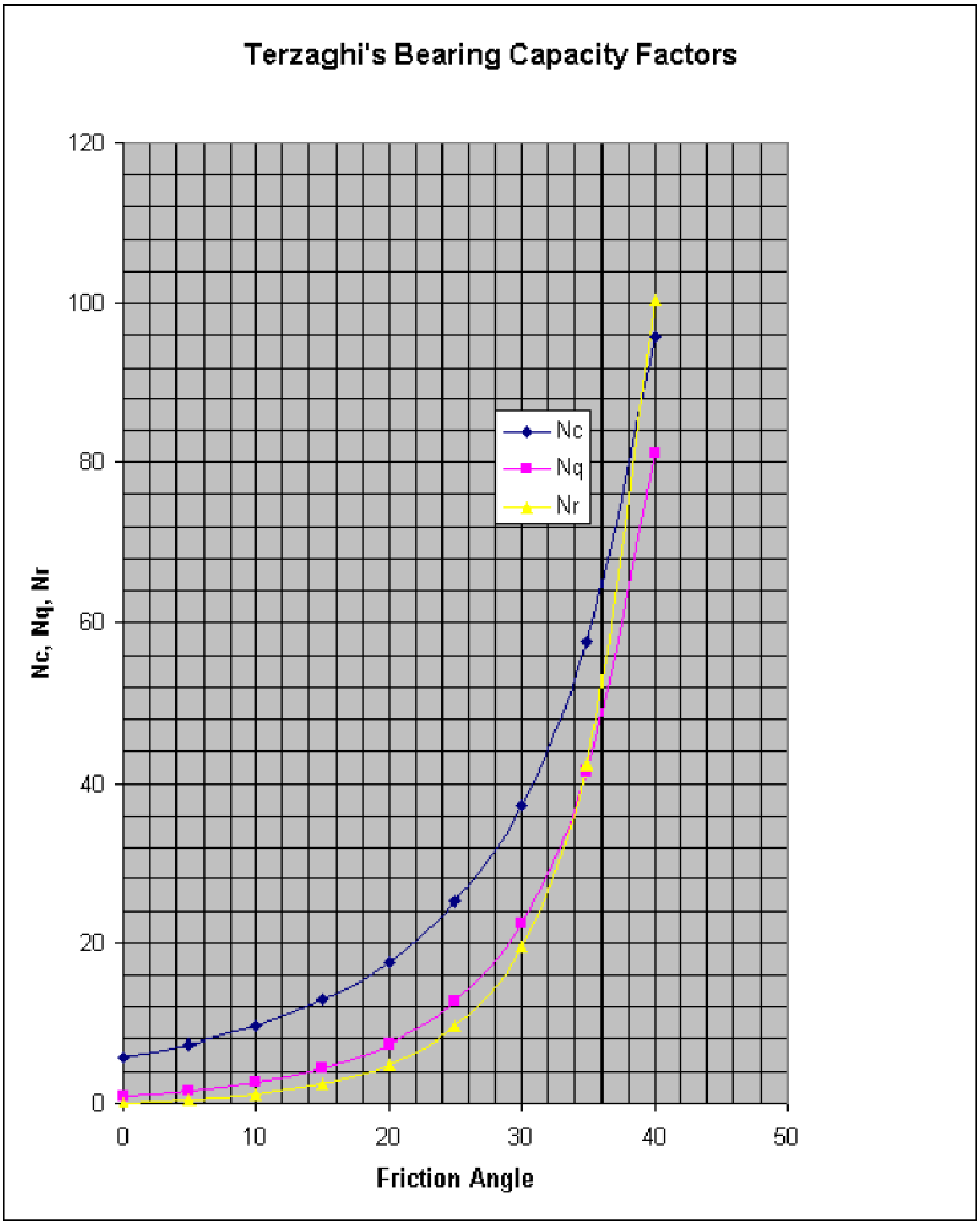
Annexure D shows the test values of Direct Shear test using method for different samples.

NORMAL STRESS(0.5KG/CM2)		
Sample	DIAL GAUGE (MM)	RING DISPLACEMENT(KN)
A1	11.34	0.064
A2	10.34	0.05
A3	7.34	0.034
B1	11.84	0.051
B2	9.34	0.036
B3	10.34	0.040
C1	9.34	0.033
C2	11.34	0.056
C3	10.34	0.050
D1	10.84	0.057
D2	10.84	0.042
D3	10.34	0.036
E1	12.34	0.061
E2	10.34	0.033
E3	10.34	0.048
N1	10.84	0.069
N2	11.34	0.058
N3	10.34	0.050
F1	10.84	0.062
F2	10.34	0.067
G1	11.84	0.049
G2	10.84	0.058
H1	11.84	0.063
H2	11.84	0.055

NORMAL STRESS(1.0 KG/CM2)		
Sample	DIAL GAUGE (MM)	RING DISPLACEMENT(KN)
A1	10.34	0.076
A2	11.34	0.058
A3	7.34	0.043
B1	11.84	0.061
B2	10.34	0.046
B3	10.34	0.052
C1	10.34	0.045
C2	11.84	0.0655
C3	10.34	0.062
D1	11.34	0.067
D2	10.34	0.052
D3	10.34	0.045
E1	11.84	0.072
E2	10.84	0.044
E3	10.84	0.055
N1	12.34	0.078
N2	11.84	0.069
N3	10.84	0.061
F1	10.84	0.073
F2	10.34	0.075
G1	10.84	0.062
G2	10.34	0.069
H1	11.34	0.074
H2	12.34	0.067

NORMAL STRESS(1.5KG/CM2)		
Sample	DIAL GAUGE (MM)	RING DISPLACEMENT(KN)
A1	11.34	0.081
A2	10.34	0.076
A3	7.34	0.053
B1	10.84	0.076
B2	10.84	0.058
B3	11.84	0.071
C1	10.34	0.061
C2	11.44	0.077
C3	12.34	0.066
D1	11.34	0.067
D2	10.84	0.060
D3	10.84	0.052
E1	11.34	0.082
E2	10.34	0.054
E3	10.84	0.064
N1	12.84	0.087
N2	11.84	0.082
N3	11.84	0.071
F1	10.84	0.080
F2	10.34	0.085
G1	10.34	0.073
G2	10.84	0.076
H1	10.84	0.083
H2	11.34	0.079

ANNEXURE E



Terzaghi's Bearing Capacity Factors
Nc
Nq
Nr
120
100
80
60
40
20
0
Nc, Nq, Nr
0
10
20
30
40
50
Friction Angle