Serial No... 1581
Date of Receipt 20/10/2017
File No... Dean R&D
Received by ...

To,

The Dean, Research and Development,
Tezpur University,
Napaam 784028

Date: 16 October 2017

Through the Head, Department of Civil Engineering, Tezpur University

Subject: Submission of project completion report under UGC Minor Research Project Scheme

Reference: *DoRD/CE/BKN/20-238*

Respected Sir

Please find enclosed herewith the Project completion report on "*Performance Evaluation of E-Waste Modified Soil and Bituminous Mixture (Registration Number: DoRD/CE/BKN/20-238)*".

I have also enclosed the final UC and SE with the project completion report.

Thanking you

Sincerely Yours

Binanda Khungur Narzary
Assistant Professor and PI
Dept. of Civil Engineering

Forwarded to Dean (R&D) for n/a pl.
16/10/17

S. mahanty
for n/a
25/10/2017

2022/01/11 11:44

Statement of Expenditure

Project Title: *Performance Evaluation of E-Waste Modified Soil and Bituminous Mixture*

Registration Number: **DoRD/CE/BKN/20-238**

Amount Sanctioned: **Rs 69,278.00 (Rupees Sixty Nine Thousand Two Hundred Seventy Eight Only)**

Expenditure

Items	Amount	Bill Forwarding Number	Reference
CBR mould and accesories	Rs 41,249.00	TU/CE/Pur/12-F.13/259; Dated: 04/01/2016	A3
Marshall apparatus mould	Rs 21, 870.00	TU/CE/Pur/12-F.13/247; Dated: 04/01/2016	A6
Total	Rs 63,119 (Rupees Sixty Three Thousand One Hundred Nine Only)		

Tezpur University

Office of the Dean, Research & Development
Napaam::Tezpur – 784028:: Assam

OFFICE ORDER
26 March, 2015

Approval is hereby accorded for implementation of the minor research project entitled ***"Performance Evaluation of E-Waste Modified Soil and Bituminous mixture"*** submitted by Mr. Binanda Khungur Narzary, Assistant Professor, Department of Civil Engineering, Tezpur University at a total cost of ₹69,278/- (Rupees sixty nine thousand two hundred seventy eight) only for a period of two years out of the amount of Rs. 56.50 lakh sanctioned vide order TU/Fin/P/14-15/192 dated 17/12/2014.

Sd/-
Dean, Research & Development
Tezpur University
Date: 26.03.2015

Memo No. DoRD/Project/10-10/5521-A

Copy to:

1. Mr. Binanda Khungur Narzary, Assistant Professor, Department of Civil Engineering, Tezpur University
2. Secretary to the Vice-Chancellor, for kind information of the V.C.
3. Registrar, Tezpur University.
4. Finance Officer, Tezpur University. A copy of the detailed project proposal is enclosed.
5. Head, Department of Civil Engineering, Tezpur University.
6. Concerned Project file.

Charu lata Mahanta 26/6/2015
Dean, Research & Development
Tezpur University

TEZPUR UNIVERSITY
INTER OFFICE MEMO

From	Dean, R&D Tezpur University	To	Mr. Binanda Khungur Narzary Assistant Professor Dept. of Civil Engineering Tezpur Universit
Ref	DoRD/Project/10-10/5445	Your Ref:	Letter dated 20/02/2015
Date	04.03.2015	Date	

This has a reference to your letter dated 20/02/2015 submitting a project proposal entitled "Performance Evaluation of E-Waste Modified Soil and Bituminous mixture" under UGC Minor Research Project Scheme. In this regard, I would like to inform you that according to Finance Section, there is no fund available under Minor Research Project head in the XII Plan. As suggested by the Finance Officer, you are requested to hold up the proposal till the receipt of additional grant from the UGC.

Chandan Lata Mahanta 4/3/2015
(C.L. Mahanta)
Dean, R&D

2022/01/11 11:44

DEPARTMENT OF CIVIL ENGINEERIN
TEZPUR UNIVERSITY
(A Central University established by an Act of Parliament)
NAPAAM :: TEZPUR – 784 028 :: ASSAM

512

Ref. TU/CE/Pur/12-F.13/259

Dt. 04-01-2016

To
The Finance Officer
Tezpur University, Tezpur

Sub: Payment request of concerned parties

Sir,

I am submitting herewith bill-cum-invoice against the supply of Transportation Engineering Laboratory items by M/s Aimil Ltd., Naimex House, A-8 Mohan Co-operative Industrial Estate, Mathura Road, New Delhi-110044 to the Dept. of Civil Engineering in December, 2015 for your needful action.

Thanking you,

Yours sincerely,

(Shailen Deka)
Head (i/c)
Dept. of Civil Engineering

H.O.D. i/c
Department of Civil Engineering
Tezpur University

Encl:

i. Original bill-cum-invoice (2 copies)
ii. Copy of the Purchase Order
iii. Financial Sanction Order
iv. Warranty Certificate
v. Summary of Balance against sanction amount

(संसद के अधिनियम द्वारा स्थापित केंद्रीय विश्वविद्यालय)
(A Central University established by an Act of Parliament)

कुल सचिव का कार्यालय/ OFFICE OF THE REGISTRAR

नपाम :: तेजपुर - 784028 :: असम

NAPAAM :: TEZPUR - 784028 :: ASSAM

Ref: TU/11-18/Pur/Civil/2015 /4800

Date: 11-3-1

To
Aimil Ltd.
"Naimex House",
A-8 Mohan Co-operative Industrial Estate
Mathura Road, New Delhi-110044.

Sub: Supply of Laboratory Equipments.
Ref: E/KOL/AIMIL/13-14/545 dated 10.03.2014.

Sir,
Kindly supply the following items required for the Transportation Engineering Laboratory, Department of Civil Engineering, Tezpur University.

Sl. No.	Item	Make	Model	Qty	Rate (in ₹.)	Amount (in ₹.)
1.	CBR mould	Aimil	AIM 12001-GM	3	6515.00	19545.[illegible]
			AIM 12002-GM	3	4825.00	14475.00
			AIM 12003-GM	3	2240.00	6720.00
					Total ₹.	40740.00
					Less: Discount 10% ₹.	4074.00
					Total after Discount ₹.	36666.00
					Add: CST 12.5% ₹.	4583.25
					Grand Total ₹.	41249.25
					Rounded Off ₹.	41249.00

(Rupees Forty One Thousand Two Hundred Forty Nine) only

Terms & Conditions:

1. The item/items should be delivered within 30 days.
2. Items should be supplied according to the specified brand name quantity and weight.
3. Low quality items will be rejected and returned to the supplier.
4. Tax/ taxes applicable to the items supplied should be shown separately in the bill.
5. Payment after delivery at Tezpur University, Napam, Tezpur, Assam.

Thanking You

Yours Sincerely

Deputy Registrar (GA)
Tezpur University

Memo No. TU/11-18/Pur/Civil/2015 /4800-A

Date: 11-3-1[illegible]

Copy for information to:

1. Finance Officer with reference to sanction no. TU/Fin/P/14-15/192 dated 17.12.2014.
2. Head, Department of Civil Engineering, Tezpur University.
3. Order File.
4. Guard File.

Deputy Registrar (GA)

2022/01/11 11:45

Aimil Ltd.
Instrumentation & Technologies

Corporate Office: Naimex House, A-8, Mohan Co-operative Industrial Estate, Mathura Road, New Delhi - 110044, India
Phone : 91-11-30810200, Fax: 91-11-26950011, Email: info@aimil.com, Website: www.aimil.com

RETAIL INVOICE

Customer C07014 TEZPUR UNIVERSITY
DEPUTY REGISTRAR (GA)
OFFICE OF THE REGISTRAR
NAPAAM,
TEZPUR - 784028
ASSAM (India)
Contact: MR. CHIRAJYOTI DOLEY, Tel: 03712-267007/8/9, 8723082052

Invoice No R114838
Dated 18/03/15

OA No. C143393
Dated 13/03/15

Consignee 00003 TEZPUR UNIVERSITY
THE HOD
CIVIL ENGINEERING DEPT
NAPAAM,
TEZPUR - 784028
ASSAM (India)
Contact: MR. CHIRAJYOTI DOLEY, Tel: 03712-267007/8/9, 8723082052

Customer Order No TU/11-18/PUR/CIVIL/2015/4800 Dated11/03/15
Worksheet No C15-1420 Dated13/03/15

No.	Description	Quantity	Unit	Unit Price	Disc %	Amount
	Shipment No. PLT145298:					
	OA No. C143393:					
AIM-12001-GM	Mould, 150mm ID x 175mm high	3	NO	5,863.50		17,590.50
AIM-12002-GM	Perforated Base Plate for AIM 12001 Mould	3	NO	4,342.50		13,027.50
AIM-12003-GM	Extension Collar 150mm ID x 50mm high	3	NO	2,016.00		6,048.00

Sub Total	36,666.00
Total Sale Value before adding CST	36,666.00
CST@ (12.5 %)	4,583.25
Total Sale Price with CST (Rs.)	41,249.25
Invoice Rounding	-0.25
Net Amount	41,249.00
	E & OE

Amount in Words RUPEES FORTY ONE THOUSAND TWO HUNDRED FORTY NINE ONLY

Make AIMIL (CIVIL)
Payment
Prices F.O.R.DESTINATION
Destination TEZPUR (DOOR DELIVERY)
Sales Tax CENTRAL SALES TAX @ 12.5%
ModeOfDispatch BY ROAD
Transporter AIMIL APPROVED TRANSPORTERS
Insurance INSURANCE TO BE BORNE BY AIMIL LTD.
100% PAYMENT AFTER DELIVERY THRU AIMIL KOLKATA

Customer's CST No. Date
Customer's LST No. Date
Customer's TIN No. UR

Received the article(s) in good condition, verified and entered in the Stock Register No. 31 Dated 18/12/15

Items are received and installed successfully in Geotech &
Technical Officer, Department of Civil Engineering, Tezpur University

Department of Civil Engineering, Tezpur University

Our Tin No. : 07730019228 PAN : AACCA7217J ... PAN Based AACCA7217JST001
Service Tax Registration No 1- Consulting Engineers - Consultancy/DL/461/AL/98 Dt. 12/03/1998 PAN Based AACCA7217JST001
Service Tax Registration No 2- Maintenance & Repair Services DL-1/ST/M&R/578/Aimil Ltd./2003 Dt. 26/09/2003 PAN Based AACCA721
Branches : Bengaluru, Bhubaneswar, Chandigarh, Chennai, Guwahati, Hyderabad, Indore, Kochi, Kolkata, Lucknow, Mu

Beyond options, Solutions

Instrumentation & Technologies

Corporate Office: Naimex House, A-8, Mohan Co-operative Industrial Estate, Mathura Road, New Delhi - 110044,
Phone : 91-11-30810200, Fax: 91-11-26950011, Email: info@aimil.com, Website: www.aimil.com

ALL Products SUPPLIED SHALL HAVE WARRANTY AGAINST MANUFACTURING DEFECTS FOR 15 MONTHS FROM THE DATE OF INVOICE OR 12 MONTHS FROM THE DATE OF INSTALLATION WHICHEVER DATE IS EARLIER. Details of applicable Terms & conditions are given in the WARRANTY POLICY card attached with the Operating Manual of the Product.

Note : No Credit of the additional duty of customs levied under sub-section (5) of section 3 of the Customs Tariff Act, 1975 have been availed/ shall be admissible.

For AIMIL Ltd.

Authorised Signatory

AIMIL LTD. is registered under the MSMED Act 2006 vide registration No. 070091200903. Section 16 of the Act will be applicable if payment is delayed beyond the terms of the order. Our CIN No. : CIN-U74899 DL1972 PLC 006093

DEPARTMENT OF CIVIL ENGINEERING
TEZPUR UNIVERSITY
(A Central University established by an Act of Parliament)
NAPAAM :: TEZPUR – 784 028 :: ASSAM

Ref. TU/CE/Pur/12-F.13/ 247

Dt. 28-10-2015

To
The Finance Officer
Tezpur University, Tezpur

Sub: Payment request of concerned parties

Sir,

I am submitting herewith bill-cum-invoice against the supply of Marshal apparatus mould with collar and base plate 100 mm by M/s Hydarulic & Engineering Instruments , A-13, Naraina Industrial Area, Phase-II, New Delhi-110028 to the Dept. of Civil Engineering in June, 2015 for your needful action.

Thanking you,

Yours sincerely,

(Shailen Deka)
Head i/c
Dept of Civil Engineering

Encl:

i. Summary of balance against sanction amount
ii. Original bill-cum-invoice(2 copies)
iii. Challan
iv. Copy of the Purchase Order
v. Sanction Order
vi. Warranty Certificate

2022/01/11 11:45

...IC & ENGINEERING INSTRUMENTS
...INA INDUSTRIAL AREA, PHASE-II
...HI-110028 (INDIA)
...: 25893820, 25893821, 25893822, 25893823
...1-25893152 GRAMS : ROCKTEST
...R IDENTIFICATION No. 0 7 4 2 0 0 3 0 6 0 2

RETAIL / TAX INVOICE

ORIGINAL- FOR BUYER

INVOICE ISSUED UNDER RULE-11 OF CENTRAL EXCISE RULE-2002	Book No.	Serial No.
PRE AUTHENTICATED	03	068

... & ADDRESS OF CONSIGNEE / BUYER
The Dy Registrar (P&A)
Tezpur University
Napaam, Tezpur-784028
Assam

...chaser's RC/TIN No. (If any)

FOR HYDRAULIC & ENGG. INSTRUMENTS
ASSESSE CODE NO. AAAFH 3487QXM001
PLA No. 1/MOD /VCH 90/97

DATE & TIME OF ISSUE OF INVOICE: 20/06/2015 12:00 hrs
DATE & TIME OF REMOVAL (IN WORDS & FIGURES): 20/06/2015 16:40 hrs

EXCISE REGISTRATION NO. AAAFH 3487QXM001

NO. & DESCRIPTION OF PACKAGES	One Box	TOTAL QUANTITY OF GOODS	12 Nos
RATE OF DUTY : BED Fully Exempt	TOTAL DUTY PAID IN FIGURES & WORDS: Nil		
ORDER NO. & DATE 11-18/U/2014 18/3/15	MODE OF DISPATCH	VEHICLE REGN. NO.	
TRANSPORT	GR. NO.	DATED	
DESCRIPTION & SPECIFICATION OF GOODS Scientific Inst			

Sl. NO.	DESCRIPTION OF GOODS	QUANTITY OR PCS	ASSESSABLE UNIT PRICE (Rs.)	ASSESSABLE TARIFF VALUE PER UNIT OR TOTAL AMOUNT
01	Marshall Apparatus Mould with Collar and Base Plate	12	1620/-	19440.00
	Total Rs.			19440.00
	E.D@			–
	E. Cess@			–
	H.E. Cess@			–
Progressive Total of Sale Rs.	Sale value before adding VAT/CST			19440.00
	(+) VAT / CST@ 12.5 %			2430.00
	Sale Price with VAT / CST			21870.00

Item has been received in good condition.
Technical Officer, Department of Civil Engineering, Tezpur University

Received the article(s) in good condition. Price(s) verified and correct. Entered in the Stock Register Page No. 19 Geotech. Lab Stock Register
Dated 20/06/15

H.O.D i/c, Department of Civil Engineering, Tezpur University

Auth. Sign./Retailer

Pay GR No 164857

Total (in words) Rupees Twenty one thousand eight hundred seventy only

DIVISION III & ADDRESS : 609, Deep Shikha Building Rajendra Place, New Delhi-110 008	SERIAL NO. OF DEBIT ENTRY IN PLA/RG-23	FOR HYDRAULIC & ENGINEERING INSTRUMENTS
RANGE 16 & ADDRESS : 506, Gagandeep Building Rajendra Place, New Delhi-110 008	TOTAL ASSESSABLE VALUE IN WORDS Nineteen thousand four hundred forty	
TARIFF HEADING & SUB HEADING No : 84.25, 84.79, 84.80, 85.14, 90.24, 90.26 90.27, 90.33, 96.04, & 72.04	Certified that the particulars given are ture and correct and the amount indicated represent the price actually charged and that there is no flow additional consideration directly or indirectly from the buyer.	(SIGNATURE OF THE OWNER OR HIS AUTHORISED AGENT)
EXEMPTION NOTIFICATION No. 12/90		E. & O. E.

Printed by: UNIQUE PRINTERS, ... Multani Dhanda, Pahar Ganj, New Delhi-55

A7

HYDRAULIC & ENGINEERING INSTRUMENTS

A-13, NARAINA INDUSTRIAL AREA, PHASE – II
NEW DELHI 110 028
Ph. No. 011-25893820/21/22/23, Fax No. 011-25893152
TIN NO : 07420030602

The Deputy Registrar (GA),
Tezpur University,
Napaam, Tezpur-784 028
Assam.

Proforma Invoice date: 14.03.2015

P.O. No. TU/11-18/Pur/Civil/2015/4801 Dtd .11.03.2015

JOB ORDER NO.370/2014-2015

Sr. No.	Item Description	Qty	Rate in Rs.	Amount in Rs.
01	**HE-SPL Marshal Apparatus mould with collar and base plate 100 mm**	12	1,800/-	21,600.00
	TOTAL			21,600.00
	Less Discount@10%			2,160.00
				19,440.00
	Excise Duty : Nil, subject to the availability of Excise Duty Exemption Certificate			
	Add CST@12.5%			2,430.00
	GRAND TOTAL			21,870.00
	(Rs.Twenty One Thousand Eight Hundred Seventy only)			

Yours faithfully
For HYDRAULIC & ENGG. INSTRUMENTS

GURMINDER SINGH
(Partner)

ACCEPTED

TEZPUR UNIVERSITY, ASSAM

H.O.D
Department of Civil Engineering
Tezpur University

2022/01/11 11:45

A8

Fax : [91,
E-mail : info
Website : www.

HEICO

Hydraulic & engineering instruments

MANUFACTURERS OF ENGINEERING, SCIENTIFIC & INDUSTRIAL INSTRUMENTS

A-19, NARAINA INDUSTR
PHASE-II, NEW DELHI

Our Ref. :

HEI/JO-370/2014-2015/ 2173

Date :

14.03.2015

The Deputy Registrar (GA) ,
Tezpur University,
Napaam, Tezpur-784 028 , Assam

Ref: P.O. No. TU/11-18/Pur/Civil/2015/4801 Dtd .11.03.2015

Dear Sir,

We acknowledge the receipt of your above purchase order for the supply of lab equipment and thank you for the same.

We are enclosing herewith the proforma invoice. You are requested to please send us the duplicate copy of the proforma duly signed and stamped as a token of your acceptance along with Road Permit & Excise Duty Exemption Certificate so as to enable us to dispatch the material within the delivery schedule.

Thanking you & assuring you of our best services at all times.

Yours faithfully
For HYDRAULIC & ENGG INSTRUMENTS

GURMINDER SINGH
(Partner)

Encl : As above
CC: HIECO Eastern Regional Office.

0/c

तेजपुर विश्वविद्यालय / TEZPUR UNIVERSITY

(संसद के अधिनियम द्वारा स्थापित केंद्रीय विश्वविद्यालय)

(A Central University established by an Act of Parliament)

कुल सचिव का कार्यालय/ OFFICE OF THE REGISTRAR

नपाम :: तेजपुर – 784028 :: असम

NAPAAM :: TEZPUR – 784028 :: ASSAM

Ref: TU/11-18/Pur/Civil/2015 /4801

To

Hydraulic Engineering Instruments

A-13, Naraina Industrial Area,

Phase-II, New Delhi-110028.

Sub: Supply of Laboratory Equipments.

Ref: HEI/1001/2013-2014/Assam/6351 dated 16.12.2014

Sir,

Kindly supply the following items required for the Transportation Engineering Laboratory, Depar Engineering, Tezpur University.

Sl. No.	Item	Make	Model	Qty	Rate (in ₹.)
1.	Marshal apparatus mould with collar and base plate 100 mm	HEICO	HE-SPL	12	1800.00
					Total ₹.
					Less: Discount 10% ₹.
					Total after Discount ₹.
					Add: CST 12.5% ₹.
					Grand Total ₹.
					(Rupees Twenty One Thousand Eight Hundred

Terms & Conditions:

1. The item/items should be delivered within 30 days.
2. Items should be supplied according to the specified brand name quantity and weight.
3. Low quality items will be rejected and returned to the supplier.
4. Tax/ taxes applicable to the items supplied should be shown separately in the bill.
5. Payment after delivery at Tezpur University, Napam, Tezpur, Assam.

Thanking You

Yours Sincerely

Deputy Registrar (GA)

Tezpur University

Memo No. TU/11-18/Pur/Civil/2015 /4801-A

Copy for information to:

1. Finance Officer with reference to sanction no. TU/Fin/P/14-15/192 dated 17.12.2014.
2. Head, Department of Civil Engineering, Tezpur University.
3. Order File.
4. Guard File.

Deputy Registrar (GA)

2022/01/11 11:46

SANCTION ORDER

I am directed to convey the financial sanction approved by the Vice Chancellor for Rs.56,50,000.00 (Rupees fifty six lakh fifty thousand) only for purchase of lab instrument

The sanction is issued against your proposal dated 16-09-2014 and old sanction no.TU/Fin/13-14/P/369 dated 05-02-2014.

The amount is debitable under the Head of Account from the budget provision made in the year-2014-15

Part :	Part-II (Plan)
Major Head :	Department of Civil Engineering
Sub-Head :	Equipment

NB: 1) The above sanction is valid up to 31-03-2015 only.
2) Payment will be made subject to availability of fund form UGC.
3) All the purchase procedure strictly be followed.

Finance Officer

Memo No. TU/Fin/P/14-15/192

Date: 17-12-2014

Copy to:

1. Head, Deptt. Of Civil Engineering, TU.
2. Concerned file

Finance Officer 17.12.14

PROJECT COMPLETION REPORT

ON

Performance Evaluation of E-Waste Modified Soil and Bituminous Mixture

Registration No.: DoRD/CE/BKN/20-238

Submitted by

Binanda Khungur Narzary

Department of Civil Engineering
Tezpur University
Napaam – 784028 Assam (India)

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

N	Newton
KN	KiloNewton
gm/cc	gram per cubic centimetre
kg	kilogram
cm	centimeter
m	meter
mm	milimeter
%	percentage
CBR	California bearing ratio
MDD	Maximum dry density
OMC	Optimum moisture content
e-waste	Electronic waste

ABSTRACT

Present study was carried out to investigate the performance of electronic waste (E-waste) modified soil and bituminous mixture. E-waste used in the study were obsolete PCs (Personal Computers) that were not in application and were intended to dispose. E-waste were brought from computer centre, Tezpur University (India). Soil for the test was collected from Napaam, Tezur (India). Soil was dried in oven in the laboratory. Plastic from the e-waste were separated and shredded into rectangular sizes of 3mm × 5mm. These were then mixed with the soil at 10%, 20%, 30% and 40% of dry weight of soil sample tested to investigate mechanical properties of soil necessary for subgrade construction. Included laboratory test were compaction test, California bearing ratio (CBR), direct shear test. The result of the e-waste mixed soil were compared with that of normal soil sample and found to be improved satisfactorily. The present study concluded that the presence of e-waste in soil enhanced the overall performance of pavement.

TABLE OF CONTENTS

1. INTRODUCTION

Flexible pavement is based on layered structure concept in which stiff layer is kept at the top and the weak layer takes the place of bottom layer. Pavement structure rest on the subgrade which takes the load of traffic ultimately. Repeated load of the traffic makes the subgrade to undergo permanent deformation or rutting. In design of the thickness of flexible pavement, stiffness of the subgrade is taken into account. Higher stiffness of subgrade soil corresponds to lesser thickness and vise-versa. This concept has introduced the soil stabilization techniques in road construction. Soil stabilization technique improves the stability or bearing power of the soil by use of controlled compaction, proportioning and addition of suitable admixtures or stabilizers. Present investigation focusses on the soil stabilization technique using proportioning method to improve the stiffness parameter of soil. In proportioning technique, soils and aggregate are mixed in suitable proportions and compacted to serve the desired objective. Objectives of soil stabilization covers increase in stability, change in properties like density or swelling, change in physical characteristics, change in chemical properties, and maintaining desired minimum strength by water proofing. Conventional proportioning techniques follows improvement of fine grained soil by addition of gravel and sand components in suitable proportions. In the present study, attempt was made to improve the locally available fine grained soil using pellets of electronic waste (e-waste) plastics. Rapid advancement of electronic technology has made consumers to discard old electronic items irrespective of their utility by a new one. Such discarded items later becomes e-waste (electronics waste) destined for reuse, recycle or disposal. Apart from the reuse and recycle, disposal of e-waste disorderly create hazard to the living things of land, water and air. Component included in the e-waste are plastic, rubber and toxic metals that take years to undergo decomposition. Globally, the figure of generation is more than 50MT (million tonnes) every year. India produces about 4 lakh tonnes of electronic waste annually. Generation of e-waste in India was 1.47 lakh tonnes or 0.573 MT per day in 2005. According to a report published by Rajya Sabha, India states that the e-waste would jump by 400 per cent on 2007 levels in China and by 500 per cent in India by 2020. Currently, 4% of total e-waste generated in India is recycled. Remaining portions of e-waste is left to handle by either informal sector or left to the ground. The issue with the informal sector is the technology to recycle the e-waste. The non-scientific and inefficient method of recycling e-waste releases hazardous toxins to the surrounding environment. In many places, e-waste is left alone freely on open ground due to lack of mechanism of collection and processing. Chances of consuming such waste by children, animal and bird is remains as a threat. Current demand is to address the issue of e-waste in India as soon as possible with more scientific method. Present study attempts to reuse the e-waste plastic in road construction work. Good quality of fine grained soil necessary for subgrade construction is always in demand and when the demand is not met, soil stabilization technique is use. In the proportioning method of soil stabilization, pellets of e-waste plastics was used instead of gravel and sand components in the present study to improve the fine grained soil. E-waste plastics was separated from the metal parts and then shredded into pallets of 3mm × 5mm. These were then mixed with the fine grained soil in proportions of 10%, 20%, 30% and 40% by weight of dry soil. Normal soil and e-waste plastic mixed soil samples were used to carry out various geotechnical test to investigate the mechanical properties. The result of the e-waste mixed soil were compared with that of normal soil sample and found to be improved satisfactorily. The present study concluded that the presence of e-waste in soil enhanced the overall performance of pavement.

REVIEW OF R&D IN THE PROPOSED AREA

It is always a challenge for the pavement engineers to construct a road with quality materials. Design standards for pavements are prepared to uphold functional and structural requirements taking into account of material properties. Unfortunately, availability of quality materials and their performance governs design and performance of such pavement in field. With the advancement of design methods, people have also understood the need of good road materials and correspondingly carried modification and improvement of conventional materials. Glassphalt, Novophalt, PMB, CRMB are such few materials to name.

The proposed study is intended to prepare composite materials by modifying conventional road materials using electronic waste suitable to construct a stable and durable road at low volume places. E-waste includes all the electronics products which include iron and plastic covers, wires, printed circuit board, glass, rubber etc. Proposed study covers all the component of e-waste excluding iron and glass. This material on dumping disorderly becomes hazardous contaminating the soil and water. Researchers and scientist throughout the world have contemplated the matter and undergone a number of studies and investigations as of now on potential application of e-waste in modification of asphalt and asphalt mixture. Following sections discusses about the studies on modification of road materials carried out in India and abroad.

2.1. National Status Review

Only few of e-waste components are found in Indian literature reporting the potential use of it in pavement construction. On the other hand, there are a nos. of reports available describing use of waste materials made of plastic and rubber in improvement of pavement structure. Although these waste materials are not extracted directly, plastic and rubber are the chief constituents of e-waste. Circuit board and other components of e-waste have not yet studied in large scale in international platform including India. Therefore, this section describes state-of-art status on utilization of waste plastic and rubber materials in pavement construction in India. It is mentioned here that the proposed study excludes metal items from the e-waste.

2.1.1. Bituminous mixture modification using e-waste

Recently waste polymer has got its importance as modifying agent due to minimum cost and easy availability to improve the mechanical properties of paving bitumen. Panda et al. (1997) attempted to develop bituminous paving binder containing reclaimed polythene extracted from polyethylene bags. It was observed that the polythene blended bitumen showed decrease in penetration, ductility and the specific gravity and increase in the softening point and viscosity. To carry out further study on this composite material, Panda et al. (2002) conducted a series of laboratory experiments to evaluate the mechanical properties of modified binder (bitumen) and mixture containing modified binder. This modified mixture on comparing with mixture containing neat bitumen found better in terms of Marshall Stability, resilient modulus, fatigue life, and moisture susceptibility.

Kumar et al. (2003) and Sridhar et al. (2004) found significant improvement in plastic waste incorporated bituminous concrete in terms of a number of physical and rheological properties. However, Kumar et al. added a naturally obtained resin along with recycled plastic at different proportions to prepare the mix. Fatigue life, Marshall Stability, ageing resistance and indirect tensile strength of composite mix were the properties found considerably increase in value. However, the percentage reduction in stability after soaking in diesel is lesser for the specimen prepared with modified bitumen than that of neat bitumen. On the contrary, Sridhar et al. (2004) reported that the modified mix has better resistance against water damage under adverse water logging condition.

Punith et al. (2004) also carried out the study on bituminous mix modified by waste plastic and found the improvement in the properties of the composite material. Modified bituminous mixture exhibited higher fatigue resistance measured under constant stress mode at different temperature compared to that of plain bituminous concrete mix.

Vasudevan et al. (2006) adopted dry process to prepare waste plastic mixed bituminous concrete. Plastic coated stone aggregate upon mixing with bitumen found higher Marshall Stability and Marshall Quotient at less binder content. Moreover, coating of molten plastic over aggregate was observed reduction in water absorption and no stripping. Punith et al. (2007) studied the behaviour of polymer modified asphalt concrete mixtures to evaluate the mechanical properties. Performance of PE (polyethylene) modified bituminous mix under dynamic creep test, indirect tensile test, resilient modulus test, and Hamburg wheel track tests found better than the conventional mix. Kumar et al. (2009) studied the rheological properties of waste plastic modified bitumen. Conventional and rheological properties of modified bitumen (before and after ageing) at different temperatures found improved. Modified bitumen performed better elastic response in Dynamic Shear rheometer. Specimen prepared with this modified bitumen was observed higher stability value compared with an unmodified one. On the other hand, Shankar et al. (2009) carried out investigation on semi dense bituminous concrete (SDBC) where shredded waste plastic is added by dry process. Based on the test results and analysis, it was observed that the modified SDBC has not only higher Marshall Stability, flow and indirect tensile strength value, but also has stronger resistance to stripping and rutting compared to conventional SDBC.

Study conducted by Sabina et al. (2009) found significant improvement in properties like Marshall Stability, retained stability, indirect tensile strength and rutting characteristics of PP (plastic/polymer) modified bituminous concrete mixes. Based on the investigation at laboratory, it was concluded that the waste PP modified bituminous concrete mixes are expected to be more durable, less susceptible to moisture in actual field conditions with improved performance.

Sreejith (2010) studied to use higher percentage of plastic waste in flexible pavement by following dry process, where aggregates were coated with plastic waste. Evaluation of bituminous mix coated with plastic waste at laboratory and at field showed better performance of bituminous mixed prepared with PCA (Plastic coated aggregate) than that prepared with plastic blended bitumen. Higher Marshall Stability value, better binding property and no stripping are the few advantages observed by Sreejith. However, Sreejith raised the issue of health hazard and environmental pollution on such technology.

Punith et al. (2011) reported the procedure for modification of 80/70 penetration grade bitumen using reclaimed polyethylene (PE) derived from low-density polyethylene carry bags. Beside the improved properties in storage stability, resistance to aging, degradation, and temperature susceptibility, modified asphalt experienced lower strains than the neat asphalt in dynamic shear rheometer test. No thermal degradation and larger elastic recovery of modified bitumen has been observed compared to that of neat bitumen.

Sangita et al. (2011) discusses on use of plastic waste to improve the road quality for Haryana state for construction of flexible pavement. Different method of preparing modified bituminous mixture using waste plastic included wet process, dry process and semi wet process. Marshall Stability, retained stability and indirect tensile strength were found higher than conventional bituminous mix irrespective of the method of approach. Moreover, formation of toxic gas was not found in the laboratory test.

Vasudevana et al. (2012) observed better performance of plastic mixed bituminous concrete in laboratory and in the field. Marshall Specimen prepared with aggregate coated by plastic (PCA) exhibited higher Stability value. And in the field too, road laid with PCA + bitumen mix found higher load bearing capacity by 100% and no formation of potholes. Shiva et al. (2012) investigate the effects of waste plastic bottles on the strength and stability characteristics of BC (bituminous concrete as surface course) mix. Marshall Stability of the modified BC was found relatively higher than that of the unmodified BC. However, stability value of specimen in water sensitivity test observed decreasing.

2.1.2. Soil modification using waste plastic

There is a gap of study and investigation in ground improvement technology using raw e-waste materials in India. Soil is the foundation of pavement taking ultimate load coming from the traffic. Subgrade formed by soil governs performance of pavement structure. Subgrade having high strength and good drainage quality is always desired by the pavement engineers as it reduces the overall thickness of the pavement structure. Thus it is always attempted to improve subgrade in site by different means, if the available soil found is poor in quality. Geo-textile, stabilization are such techniques carried out commonly in field in such cases. Recently civil engineers are attempting to find potential use of solid waste materials for soil improvement. Proposed study is attempted to use e-waste as the solid waste for soil improvement purpose. Currently, however no such study and investigations are carried out. Instead of that, a no. of reports is available stating the possible use of waste plastic for soil improvement. Following section discusses the state-of-art on the use of waste plastic in soil improvement in India.

Rao et al. (2004) investigated the performance of soil mixed with waste plastic strip. Strips of carry bags and packaging materials were mixed with sand in dry condition soil and then performance was measured using laboratory triaxial test. Based on laboratory tst and analysis, it was concluded that the bearing capacity of granular trench increases when sand-waste plastic mixtures is used. Similar attempt was made by Dutta et al. (2007) to improve the subgrade soil, where stone dust and fly ash were reinforced with waste plastic strip. Laboratory samples were prepared by keeping these composites over saturated clay. From the CBR behaviour of the samples, it was concluded that the material could be used for base course construction for low volume roads over saturated clay. Prasad et al. (2009), Choudhury et al. (2010), Bhattarai et al. (2013) and Poweth et al. (2013) used plastic strips as soil reinforcing material in their study to improve strength and deformation behaviour of subgrade substantially.

Asraf et al. (2011) carried out investigation on raw plastic bottles and its strips as a soil stabiliser. Plate load test was carried out on layers of soil reinforced by plastic strips, sand filled plastic bottles, half cut and then sand filled bottle placed at middle and 1/3 position of test tank. Amount of plastic strips needed plastic strip reinforced sand was determined from CBR test. Based on the result and analysis, it was concluded that the soil stabilisation using cut bottles placed at middle position were the most efficient in increasing strength of soil

Subramania et al. (2012) studied the effect of fibre of waste plastic on the performance of stabilised mud block. Fibres chopped from carry bags and mineral water bottle were mixed with soil containing lime and cement. Mud blocks made from this reinforced soil were brought to carry out laboratory test. From the test results, it was observed that the performance of mud block is better in compared to raw soil in terms of strength, ductility and post cracking characteristics. Similar study was performed by Bhattarai et al. (2013) and Poweth et al. (2013). However, Poweth et al. added stone dust along with soil and plastic waste. Non-recyclable plastic waste of plastics processing unit was added with soil. The observation found that soil and plastic mixture on adding stone dust shows higher CBR value as soil and plastic mix alone showed decrease in maximum dry density.

2.2. International Status Review

Study on e-waste materials started with development of various recycling technology. Few studies were carried out on recycling of e-waste plastics by Achilias et al. (2009), Anandhan et al. (2002), Yokoyama et al. (1995) and Li et al. (2007). However, Jeong et al. (2010) attempted to use waste polyethylene (WPE) film in asphalt mixture to improve its performance. Optimum WPE was measured using conventional Marshall Method. From the results, it was observed that asphalt mixture containing WPE had higher Marshall Stability, indirect tensile strength and better rutting characteristics compared to normal asphalt mixture without WPE. Colbert (2012) studied extensively on potential application of e-waste for improvement of asphalt and asphalt mixture. Plastic of e-waste was grinded into powder before adding to asphalt. Addition of e-waste was made in two ways. In first case, e-waste was added directly to the asphalt mixture. In the second case, e-waste was treated with chemicals and then added to the asphalt mixture. The study concluded that e-waste added asphalt mixture performs better than control mixture. Rutting susceptibility, dynamic modulus at low temperature and limited emission-performance are the few improvements found in the study. However quantity and compatibility matter between asphalt and e-waste plastic is yet to be studied to derive maximum performance. On further literature review, reports were studied, which were based on waste plastic materials that has been used for modification of bitumen and bituminous mixture.

2.2.1. Bituminous mixture modification using e-waste

Jew et al. (1986) observed that the use of polyethylene in asphalt hot-mix paving materials could extend service temperature range at both high and low temperatures. Dynamic mechanical measurements, Marshall Properties and flexural test at low temperature exhibited consistent with the published data for commercial Novophalt paving materials developed in Austria. Later, Ramona et al. (1991) found that polyethylene terephthalate (PET) changes the flow properties and expansion coefficient of asphalt binder. The PET filler acts as a binder, restricting the flow of the asphalt until the filler itself starts melting. However, the overall flow of the mixture is dominated by the flow properties of PET.

Flynn (1993) discusses the reuse of waste plastic as an asphalt cement modifier in highway. Plastic waste contains polyethylene and polypropylene, which was added with asphalt. Plastic mixed asphalt found better performance than unmodified asphalt in the laboratory and in the field. In addition to it, the mix found suitable from economic and environmental point of view.

Zoorob et al. (2000) developed a new material called Plastiphalt, composed of continuously graded asphalt concrete containing recycled plastic aggregate to replace a portion of mineral aggregate. Plastiphalt exhibited improvement in engineering properties. Marshal Stability, resistance to deformation and static indirect tensile strength of plastiphalt found better than that of the control mix. Although Plastiphalt mix provides remarkable elastic recovery, it has lower creep stiffness and indirect tensile stiffness modulus values than that of the control mix. Garcia-Morales et al. (2004) mixed the recycled EVA/LDPE (ethylene vinyl acetate copolymer and low-density polyethylene) to modify the properties of bituminous binder. Study showed that polymer on blending with bitumen modifies the melt processing characteristics of bitumen, whilst the viscoelastic properties of the semi-solid composite are enhanced. This enhancement of viscosity was reported to provide better mechanical properties of bitumen in the temperature region where the material is used as a surface coating. Hinislioğlu et al. (2004) observed higher Marshall Stabiltiy and Marshall Quotient values of waste plastic modified bituminous mix than that of conventional mix. Casey et al. (2008) selected LDPE and HDPE (Low and high density polyethylene) as the suitable polymer contained in waste plastic material, based on the laboratory test to find its compatibility with bitumen. Bituminous mixture prepared with selected polymer and bitumen results in better performance under wheel tracking test and indirect tensile fatigue test. Abdel-Goad (2009) concluded that plastic bag could be an alternative material to modify bitumen, suitable for both environmental and economical points of view, based on rheological study. Moreover, addition of waste plastic to bitumen also found enhancing the stability of the blend.

Mahrez et al. (2010) and Kalantar et al. (2010) evaluated the rheological properties of bituminous binder modified by waste plastic material. The recycled PET modified bitumen showed higher softening point and viscosity, lower penetration value and better viscoelastic properties (higher complex shear modulus and lower phase angle) indicating the higher resistance to rutting and permanent deformation compared to that of original binder.

Rahman et al. (2011) evaluate the recycled high-density polyethylene (HDPE) modified bitumen. The finding indicates that the addition of recycled HDPE to bitumen enhances the conventional and morphology properties of the modified binder. Moreover, decrease in penetration, increase in softening point and PI (Penetration Index) were observed, indicating an increment in hardness or stiffness properties of the HDPE modified bitumen. The study reported that the flexible pavement constructed with such modified bitumen could resist the pavement failures. Rasel et al. (2011) used the binding property of molten PVC (Polyvinyl Chloride) obtained from domestic waste to modify the properties of bituminous concrete mix. Marshall Parameters of the PVC mixed bituminous concrete was observed well within the acceptable recommended limits specified by AASHTO. Based on the experimental results of stability, stiffness and void characteristics, the study concluded that the dense graded bituminous concrete containing waste PVC could be used for flexible pavement construction in warmer region. Silva et al. (2011) concluded that the bituminous mixtures incorporating waste polymers could be a suitable material for paving works from technical and environmental point of view. Evaluation of asphalt mixtures added with polyethylene (high density polyethylene (HDPE) and cross-linked polyethylene (PEX) based wastes material in asphalt mixtures, showed significant performance in terms of water sensitivity, permanent deformation resistance and temperature susceptibility. Similar results were also been observed by Ahmadinia et al. (2011). Incorporation of waste plastic bottles to asphalt mixture produces higher stiffness of asphalt mixture improving its resistance level against permanent deformation at volumetric and Marshall Properties within the acceptable region. Based on all these improved properties Ahmadinia et al. concluded that paving with plastic modified bitumen would be helpful for not only to road construction but also from economy and environmental solid waste management sight.

Nassar et al. (2012) studied morphology and thermal properties of modified bitumen prepared by adding waste Polystyrene. Apart from the observation of the improvement in physical properties of modified bitumen over unmodified one, it was also found that polymers contained in the waste materials are compatible with bitumen, which imparts thermal stability to the asphalt. On the basis of observations, Rahman et al. (2013) reported that waste polyethylene modifier and waste PVC modifier can be used for flexible pavement construction in warmer region from the standpoint of stability, stiffness and voids characteristics. Evaluation of properties of modified binder and modified binder mixture found reasonably well. Some of the measured properties of asphalt mixture with the modifier used in the study were within the acceptable recommended limits, which it concluded that the polyethylene and PVC could be used to prepare dense graded asphalt concrete.

2.2.2. Soil modification using E-waste: international status review

E-waste has not been studied for modification or stabilisation for pavement construction. Plastic and circuits boards which are the major components of e-waste could be potential materials to be used as a soft aggregate for base course and subgrade. However, research has been progressed in soil stabilisation techniques using waste plastic. Fletcher et al. (1991) added polypropylene fibre with soil and found improvement significantly in CBR value ranging from 65 to 133% over normal soil. Craig et al. (1994) used strips of plastic prepared from reclaimed HDPE (High Density Polyethylene) in the aspect ratio of 4, 8 and 12 to investigate its effect on sand soil reinforcement. Results and analysis showed that addition of strip increased the engineering properties of soil which includes CBR value, secant modulus, resilient modulus and shear strength. However, properties of reinforced sand were dependent on the aspect ratio. Similar study was also conducted by Nilo et al. (2002), in which strips of plastic bottles were randomly mixed with sand to improve the engineering behaviour of the composite. Bueno et al. (1997) extended similar investigation on soil of three different types mechanically stabilized soil with plastic strip. Plastic strip stabilized gneiss residual soil, sand soil and manmade soil were brought to carry out a series of laboratory test. The results showed that the presence of plastic strip improves strength, load bearing capacity, ductility, permeability and compressibility.

Sobhan et al. (2003) to evaluate the mechanical behaviour of waste plastic strip reinforced soil containing cement and fly ash. Strip of waste HDPE was added to cement sand and fly ash mixture. It was observed from the laboratory data that combination of cement, fly ash added soil on reinforcement with plastic strip held higher compressive strength, split tensile strength suitable for base course of a pavement. It was also observed that addition of plastic strip significantly increases the postpeak load carrying capacity and thus the fracture energy of the soil composite. Further study and investigation on soil reinforcement using waste plastic was conducted by Kulmba et al. (2013), in which plastic strips were reinforced with sand soil. Polyethylene shopping bags are cut into strips of length 15mm to 40mm and width 6 mm to 18 mm were mix randomly with soil and Shear strength parameters were obtained. The laboratory data and analysis carried out in the study showed that the soil plastic strip composite materials perform effectively in some geotechnical application as the fibre of plastic acts as tensile member. However, study on soil-plastic interaction mechanism was kept for future work. Although nos. studies have been carried out on plastic fibre reinforced soil since last two-three decades, plastic used in most of study were not recycled from waste plastic materials. Such studies include Gray et al. (1983), Freitag (1986), Kumar et al. (1999), Kaniraj et al. (2001), Tang et al. (2007) and many more. Those reports are discarded in this section as the proposed study is on investigating potential use of e-waste in pavement construction.

2.3. Summary

E-waste has not been taken for investigation to learn its effect on the pavement structure at large scale. E-waste composed of many materials including plastic, metals, glass etc. Colbert (2012) attempted to use only e-waste plastic to improve performance of asphalt mixture. Few reports were also published discussing recycling technologies of e-waste plastic. There are a nos. of reports has published already on the use of waste plastic to improve characteristic of soil and asphalt mixture. IRC: SP-98-2013 provides guidelines for the use of waste plastic in hot bituminous mixes (dry process) in wearing courses. Many have also observed better performance of plastic reinforced soil to be use in subgrade and base layer. However, the technology is yet to be getting its popularity among the pavement and environmental engineers.

OBJECTIVES OF THE STUDY

After going through extensive literature survey, following observations have been made.

1. Study should be carried out on other components of e-waste including plastic. Considering only the plastic part of e-waste again leaves other e-waste at landfills again. Therefore a method is needed where all different types of e-waste excluding recyclable waste could be used. This would reduce the e-waste to higher amount.

2. Technology demands simplicity and easy to be adopted. Heavy machinery and complicated procedurals are avoided as far as possible at site as such methods scale up construction cost to higher range and skilled personals are necessary. Lengthy and difficult treatments of waste plastics or e-waste to make suitable for pavement construction needs strong supervision.

3. Methods of modifying asphalt mixture and soil using waste plastics, published previously were based on selection of plastic type. IRC: SP-98-2013 specified to use different type of waste plastic in hot bituminous mixes. However, plastic and other waste emerging from e-waste could be used as soft aggregate in pavement construction.

4. Previous studies and investigations were intended to describe about the potential application of e-waste in road construction based on laboratory test. Permanency of strength and compaction and better drainage characteristics of road materials are the

desirable properties that need to be addressed in detail when materials are modified with e-waste.

3.1. Objective

Following are the objective set in the proposed study

1. Evaluation of compaction characteristic of soil and e-waste modified soil.
2. Evaluation of shear strength characteristics of soil.
3. Evaluation of unsoaked CBR value of soil and e-waste modified soil.
4. Evaluation of soaked CBR value of soil and e-waste modified soil.

MATERIALS AND METHODOLOGY

The following section discuss the materials and the methodology followed in the present investigation.

The materials that were required for the soil and e-waste. The soil was collected from Naapam, Tezpur (Assam). The soil was dried in oven for 24 hours and pulverized in the laboratory. The e-waste was collected from computer centre, Tezpur University, (India). Included e-waste in the study were keyboard, mouse, CPU and monitor. The plastics were separated from the metal parts of e-waste in the laboratory. E-waste plastics were later shredded manually into the rectangular size of 3mm × 5mm.

Work done in the study can be divided in the following parts:

4.1. The preliminary tests on soil are-

1. Sieve analysis of soil
2. Specific gravity of soil
3. Wet sieve analysis of soil
4. Atterberg's limit of soil
5. Proctor test of soil
6. California bearing ratio test of soil

4.1.1 Sieve analysis of soil

Theory

The size of fine aggregate is limited to a maximum of 4.75 mm gauge. Sieve analysis is carried out to determine the grading zone of fine aggregate.

Procedure

1 kg of soil is taken from the laboratory sample. Then the sieves are arranged in order of 4.75mm, 2.36mm, 1.18mm, 600 microns, 300microns, 150microns. Keeping sieve 4.75mm at the top and 150microns at the bottom and cover the top. Then the sample is kept in the top sieve (4.75mm). Then the sieving in carried out in the set of sieves for not less than 10 minutes. Then the weight of sample retained in each sieve is calculated.

4.1.2 Specific gravity of soil

Theory

Specific gravity is the ratio of the mass/weight in air of given volume of dry soil to the mass/weight of equal volume of distilled water at 4°C. Its value helps us in identification and classification of soil. The specific gravity of soil is made use of in calculations of CBR test

Procedure

Firstly the weight of an empty clean and dry pycnometer is recorded. Then 10g of soil is placed in the pycnometer and then the weight of the pycnometer containing the soil is taken. Then distilled water is filled to about half to three-fourth of the pycnometer. Then the samples are soaked for 10 minutes. Then a partial vacuum is applied to the contents for 10 minutes to remove the entrapped air. The vacuum is stopped and carefully the vacuum line is removed from pycnometer. The pycnometer is filled with distilled (water to the mark), the exterior surface of the pycnometer is cleaned with a clean, dry cloth. Then the weight of the pycnometer is determined and recorded. After that the pycnometer is emptied and cleaned. Then it is filled with distilled water only and the exterior surface of the pycnometer is cleaned with a clean, dry cloth. Then the weight of the pycnometer with the distilled water is taken and lastly to empty the pycnometer and to clean it and have to record the temperature of the content in degree centigrade and have to repeat this test twice more.

W_1= weight of container

W_2= weight of container + soil

W_3= weight of container +soil + water

W_4= Weight of container + water

$$\text{specific gravity}=\frac{W_2-W_1}{(W_2-W_1)-(W_3-W_4)}$$

4.1.3 Wet sieve analysis of soil

Theory

Sieve analysis wass carried out to determine the gradation of sample soil under study.

Procedure

The portion of the soil passing 4.75mm IS Sieve obtained as given in 3.2 was oven-dried at 105 to 110°C. The oven-dried material was then riffled so that a fraction of convenient mass is obtained. The riffled and weighed fraction was spread out in the large tray and covered with water. A solution of two grams of sodium hexametaphosphate per litre of water was prepared and the soil was added to it. The mix was thoroughly stirred and left for soaking. The soil soaked specimen was washed thoroughly over the nest of sieves with the finest sieve 75-micron IS Sieve at the bottom. Washing was continued until the water passing each sieve is substantially clean. The fraction retained on each sieve was emptied carefully without any loss of material in separate trays. The sample was oven dried at 105 to 110°C and each fraction weighed separately and the masses recorded.

Fig. 4.1: Wet sieve analysis of soil

4.1.4. Atterberg's limit of soil: Plastic limit of soil

Theory

This test was done to determine the plastic limit of soil as per IS: 2720 (Part 5) – 1985. The plastic limit of fine-grained soil is the water content of the soil below which it ceases to be plastic. It begins to crumble when rolled into threads of 3mm diameter.

Procedure

First about 8g of the soil is taken and rolled it with fingers on a glass plate. The rate of rolling was maintained between 80 to 90 strokes per minute to form a 3mm diameter. The rolling was continued till the diameter of the threads reduced to less than 3mm, without any cracks appearing. The process of alternate rolling and kneading is repeated until the thread crumbles. Then the pieces of crumbled soil was kept in the container to determine the water content using oven drying method. The process is repeated at least twice more with fresh samples of plastic soil each time.

4.1.5. Atterberg's limit of soil: Liquid limit of soil

Theory

This test was done to determine the liquid limit of soil as per IS: 2720 (Part 5) – 1985. The liquid limit of fine-grained soil is the water content at which soil behaves practically like a liquid, but has small shear strength. Its flow closes the groove in just 25 blows in Casagrande's liquid limit device.

Procedure

First a portion of the paste was placed in the cup of the liquid limit device. The mix was leveled so as to have a maximum depth of 1cm. The grooving tool was drawn through the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup. For normal fine grained soil the casagrande's tool was used to cut a groove 2mm wide at the bottom, 11mm wide at the top and 8mm deep. After the soil pat had been cut by a proper grooving tool, the handle was rotated at the rate of about 2 revolutions per second and the no. of blows counted, till the two parts of the soil sample come into contact for about 10mm length. Then about 10g of soil was taken near the closed groove and its water content was determined. The soil of the cup was transferred to the dish containing the soil paste and mixed thoroughly after adding a little more water. The test was repeated. By altering the water content of the soil and repeating the foregoing operations at least 5 readings were obtained in the range of 15 to 35 blows. Dry soil were not allowed to mix to change its consistency. Then liquid limit was determined by plotting a 'flow curve' on a semi-log graph, with no. of blows as abscissa (log scale) and the water content as ordinate and drawing the best straight line through the plotted points.

4.1.6 Proctor test of soil

Theory

Compaction is the process of densification of soil mass by reducing air voids. The purpose of laboratory compaction test is so determine the proper amount of water at which the weight of the soil grains in a unit volume of the compacted is maximum, the amount of water is thus called the Optimum Moisture Content (OMC). In the laboratory different values of moisture contents and the resulting dry densities, obtained after compaction are plotted both to arithmetic scale, the former as abscissa and the latter as ordinate. The points thus obtained are joined together as a curve. The maximum dry density and the corresponding OMC are read from the curve.

Procedure

About 20 kg of soil was taken and sieved it through 20 mm and 4.75 mm. A 100 mm diameter Proctor mould was used for the study. Then about 5 kg of the soil sample was taken and water was added to make the soil partially moist. The mix was left to mature for few minutes. The inside surface of the mould and the base plate was cleaned and greased. Then the weight of empty mould with the base plate was taken. The collar was fixed and the mould was placed on a solid base. First batch of soil was placed inside the mould and 25 blows of standard rammer weighing 4.9 kg is applied, so that the compacted layer thickness is about one-fifth height of the mould. Then the top of the compacted soil was scratched before the placing of second layer. The second batch of wet soil was placed and the same procedure was followed. Similarly, the soil was compacted in five layers, each given 25 blows of the standard rammer and having a drop of 450 mm. Then the collar was removed, and the excess soil was trimmed with trimming knife. The mould is cleaned, and weighted the mould with the compacted soil and the base plate. A representative sample from the mould was taken and its water content was determined. The above procedure is repeated by adding water and continued until the weight of the soil filled in the mould reduced.

4.1.7 California bearing ratio of soil

Theory

California Bearing Ratio or CBR is the ratio of force per unit area required to penetrate into a soil mass with a circular plunger of 50mm diameter at a rate of 1.25mm per minute. The value represents the strength of the soil.

Procedure

First of all the weight of the empty mould (2250cc) capacity with its base plate and extension collar was taken (m_1). Then the oven dried sample soil weighing 5 kg was mixed thoroughly at OMC. After removing the extension collar from the mould the spacer disc was inserted inside the mould over the base plate and then a coarse filter paper was placed on the top of the spacer disc. Then the mould was placed upon the concrete floor and the wet soil in the mould was compacted, 5 layers each approximately with equal mass, each layer by giving 55 blows with a 4.9kg hammer equally distributed and dropped from a height of 450mm above the soil. The amount of the soil used was taken sufficiently in filling the mould, leaving not more than about 6mm to be struck off when the extension collar is removed. Then the extension collar was removed and the compacted soil was carefully leveled to the top of the mould by means of a straight edge. After that the spacer disc was removed by inverting the mould and the weight was measured with the compacted soil (m_2). Now, before leaving it into soaked condition, representative samples of the material were taken at the beginning of the compaction and another sample after the completion of the compaction for determining the moisture content. First for unsoaked condition CBR test was performed after weighing the mould with sample, then for the soaked condition the same above procedure was repeated with the same sample soil mass after placing the adjustable stem and perforated plate on the compacted soil specimen in the mould. Then both the ring weights were placed 2.5kg each on the perforated plate to produce enough surcharge equal to the weight of the base plate. Then the whole mould was immersed and weights in a tank of water allowing free access of water to the top and bottom of the specimen for a time period of 96 hours. After 96 hours of soaking, the specimen were taken out from the water tank and the extension collar, perforated disc, surcharge weights and filter paper were removed. Then the excess water was drained off by placing the mould inclined for about 15 minutes and weigh the mould. Then the mould was placed on the lower plate of the testing machine with top surface exposed. To prevent upheavel of soil into the hole of surcharge weights, annular disk of weights 2.5 kg was placed on the soil surface prior to seating the penetration plunger after which place the reminder of the surcharge weights. Then the plunger was allowed to penetrate under a load of 4kg to establish the full contact between surface of the specimen and the plunger. After setting the stress and strain gauges to zero considering the initial load applied to the plunger as the zero load. Then the load was applied at a rate of 1.25mm per minute. Then the readings were taken at a penetration of 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5,.......12.5. Then the plunger is raised and the mould is detached from the loading equipment. Then the sample is collected of about 20g to 30g of soil from the top 30mm layer of the specimen for determining the water content in accordance with IS:2720(part 4) 1973.

Fig. 4.2: CBR test of soil

4.1.8. Direct shear test

Theory

Direct shear test was carried out to determine the shear strength of soil as per IS: 2720 – 1986 (Part 13). The soil sample in the test is sheared horizontal under the application of vertical loads.

Procedure

The soil sample was added with water to achieve optimum dry density. The moist soil is then poured in the confined metal box of square cross-section that is split into two halves horizontally. The soil then kneaded to provide compaction equal to maximum dry density. Solid metal plates were used above the specimen. A pressure pad was placed on top and the entire box in placed in the trolley of direct shear box apparatus. One half of the box is pushed relative to the fixed one. A vertical load is applied to the specimen through a static weight hanger and the soil was sheared gradually by applying a horizontal force which causes the two halves of the box to move relative to each other. The shear is normally applied at a constant rate of 1.25 mm/min. the magnitude of the shear load was measured by proving ring and the deformation was by dial gauges. The procedure was repeated on three samples, each subjected to a different vertical load. Normal stress and the shear stress on the failure plane were obtained by diving the normal force and the shear force by the nominal area of the specimen. Values of shear stress at failure are plotted against the normal stress for each test. The shear strength parameters c and φ parameters were obtained from the best fit line through the points.

4.2 The preliminary tests on e-waste are-

1. Sieve analysis of e-waste
2. Specific Gravity of e-waste
3. Impact value test of e-waste
4. Proctor test of e-waste

   Proctor test of e-waste using 10% waste

   Proctor test of e-waste using 20% waste

   Proctor test of e-waste using 30% waste

   Proctor test of e-waste using 40% waste
5. California Bearing Ratio of e-waste

   California Bearing Ratio of e-waste using 10% waste

   California Bearing Ratio of e-waste using 20% waste

   California Bearing Ratio of e-waste using 30% waste

   California Bearing Ratio of e-waste using 40% waste

4.2.1 Sieve analysis of e-waste

Theory

Sieve analysis is carried out to determine the gradation of shredded e-waste.

Procedure

1 kg of e-waste was taken from the laboratory sample. Then the sieves were arranged in order of 75mm, 53mm, 20mm, 10mm, 4.75mm, 2mm, 0.425mm, .075mm. Keeping sieve 4.75mm at the top and 150microns at the bottom and cover the top. Then the sample was kept in the top sieve (4.75mm). Then the sieving was carried out in the set of sieves for not less than 10 minutes. Then the weight of sample retained in each sieve was calculated.

Fig. 4.3: Sieve analysis of soil

4.2.2 Specific gravity of e-waste

Theory

Specific gravity is the ratio of the mass/weight in air of given volume of material to the mass/weight of equal volume of distilled water at given temperature.

Procedure

Take about 500g of sample and place it in the pycnometer. Pour distilled water into it until it was full. Eliminating the entrapped air by rotating the pycnometer on its side, the hole in the apex of the cone being covered with a finger. Wipe out the outer surface of pycnometer and weigh it (W). Then the content of the pycnometer was transferred in to a tray. The pycnometer was refilled with distilled water to the same level. The weight (W1) was measured. The sample was then kept in air for 24±0.5 hours to dry. The sample was then weight (W2).

Fig. 4.4: Specific gravity of e-waste of e-waste

4.2.3 Impact value test of e-waste

Theory

The property of a material to resist impact is known as toughness. Due to movement of vehicles on the road the materials are subjected to impact resulting in their breaking down into smaller pieces. The materials should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test. The material impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

Procedure

The test sample consists of materials sized 10.0 mm 12.5 mm. the e-waste was sieved through 12.5 mm and 10.0mm IS sieves. The materials passing through 12.5mm sieve and retained on 10.0mm sieve comprises the test material. The e-waste was poured to fill the measuring cup of about just 1/3[rd] depth of measuring cylinder. The e-waste sample was then compacted by giving 25 gentle blows with the rounded end of the tamping rod. Two more layers were added to the cup in similar manner, so that cylinder is full. Then surplus part was strike off. The net weight of the materials (W) was measured in balance. The sample was brought to the impact machine. The cup was fixed firmly in position on the base of machine and placed whole of the test sample in it and compact by giving 25 gentle strokes with tamping rod. The hammer was raised until its lower face is 380 mm above the surface of material sample in the cup and allowed it to fall freely on the material sample. 15 such blows at an interval of not less than one second was applied. The crushed material was removed from the cup and sieve it through 2.36 mm IS sieves until no further significant amount passes in one minute. The fraction passing part was weighted.

4.2.4 Proctor test of e-waste soil mixture

Theory

Compaction is the process of densification of soil mass by reducing air voids. In this experiment, different percentage of e-waste (10%, 20%, 30%and 40%) is mixed with soil and test is carried out.

Procedure

About 20 kg of soil was taken and sieved it through 20 mm and 4.75 mm. A 100 mm diameter Proctor mould was used. Then about 5 kg of the soil sample and 500 gm of e-waste were mixed and water was added to make the soil mixture wet. The mix was left to mature for few minutes. The inside surface of the mould and the base plate was cleaned and greased. Then the weight of empty mould with the base plate was taken. The collar was fixed and the mould was placed on a solid base. First batch of soil was placed inside the mould and 55 blows of standard rammer was applied, so that the compacted layer thickness was about one-third height of the mould. Then the top of the compacted soil was scratched before the second layer was placed. The second batch of wet soil was placed and the same procedure was followed. In all the soil was compacted in three layers, each given 55 blows of the standard rammer weighing 4.75 Kg and having a drop of 450mm. Then the collar was removed, and the excess soil was trimmed with trimming knife. The mould was cleaned, and weighted the mould with the compacted soil and the base plate. A representative sample from the mould was taken and its water content was determined. The above procedure was repeated for water content values of 13%, 17%, 20%, 22% and 25%. Similar procedure was repeated for sample containing soil and e-waste of percentage 20%, 30% and 40% by weight of dry soil.

4.2.5 California bearing ratio test of e-waste soil mixture

Theory

California Bearing Ratio or CBR is the ratio of force per unit area required to penetrate into a soil mass with a circular plunger of 50mm diameter at a rate of 1.25mm per minute. Here in this experiment different percentage of e-waste (10%, 20%, 30%and 40%) was mixed with soil and the test is carried out.

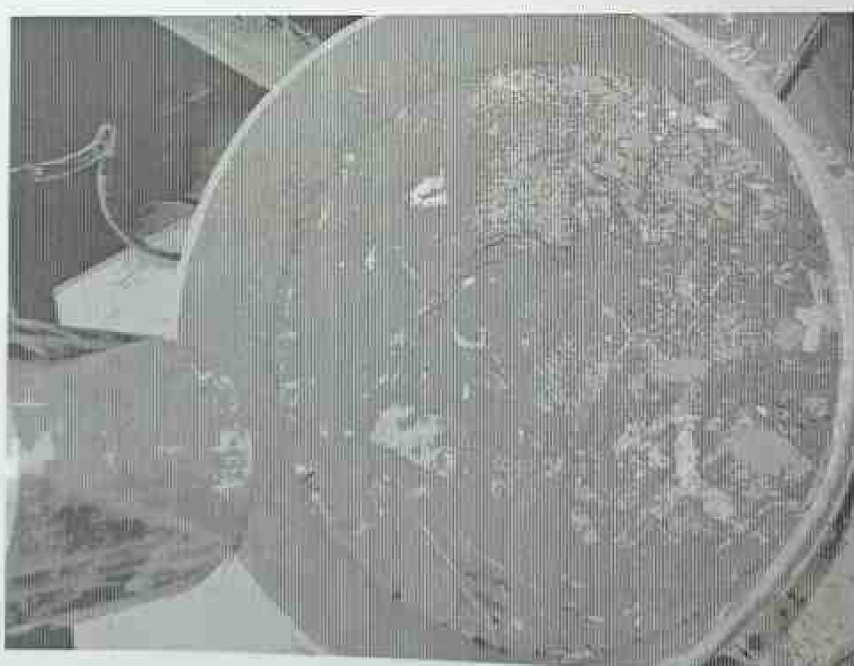

Fig. 4.5. CBR test of 30% e-waste mixed soil

Procedure

Weight of the e-waste soil mixture required for the CBR test were determined from the maximum dry density (MDD) obtained from the proctor test. Water was added to the e-waste soil mixture to achieve the optimum moisture content (OMC). Compaction of the sample was carried out with rammer of 4.9kg, after filling it in CBR mould in layers. A total of five layers were laid and compacted for 55 times per layer. Compacted CBR samples were prepared for unsoaked and soaked conditions. The procedure was repeated for the e-waste soil mixture containing e-waste 10%, 20%, 30% and 40% by weight of dry weight of soil.

4.2.6 Direct shear test of e-waste soil mixture

The soil sample in the test is sheared horizontal under the application of vertical loads. Here in this experiment different percentage of e-waste (10%, 20%, 30%and 40%) was mixed with soil.

Procedure

The required amount of oven dried soil sample and the e-waste were added with water to achieve optimum dry density. The moist e-waste soil mixture was then poured in the confined metal box of square cross-section that is split into two halves horizontally. The e-waste soil mixture then kneaded to provide compaction equal to maximum dry density. Solid metal plates were used above the specimen. A pressure pad was placed on top and the entire box in placed in the trolley of direct shear box apparatus. One half of the box is pushed relative to the fixed one. A vertical load is applied to the specimen through a static weight hanger and the soil was sheared gradually by applying a horizontal force which causes the two halves of the box to move relative to each other. The shear is normally applied at a constant rate of 1.25 mm/min. the magnitude of the shear load was measured by proving ring and the deformation was by dial gauges. The procedure was repeated on three samples, each subjected to a different vertical load. Normal stress and the shear stress on the failure plane were obtained by diving the normal force and the shear force by the nominal area of the specimen. Values of shear stress at failure are plotted against the normal stress for each test. The shear strength parameters c and φ parameters were obtained from the best fit line through the points. The procedure was repeated for the e-waste soil mixture containing e-waste 10%, 20%, 30% and 40% by weight of dry weight of soil.

RESULTS AND DISCUSSION

This chapter contains the calculations and results of all the experiments performed on the test soil and soil mixed with sugarcane bagasse.

5.1. Grain Sieve Analysis

5.1.1. Dry sieve analysis

Wt. of the soil sample taken for analysis, gm = 1458.50 gm

Colour of the soil = brownish yellow

Table 5.1 dry sieve analysis

IS sieve	Wt. retained (gm)	% retained	Cumulative % retained	% finer
100.0	0.0	0.0	0.0	100.0
75.0	0.0	0.0	0.0	100.0
19.0	0.0	0.0	0.0	100.0
4.75	62.4	4.2	4.2	95.8
Pan	1423.1	95.8	-	-

Dry sieve analysis shows that the soil sample brought for the investigation is belong to fine grained category. Therefore, wet sieve analysis was carried out to investigate the particle size distribution of soil sample below 75 micron. Fraction passing through the 75 micron sieve was then used for plummet balance test to further determine the silt and clay content. Table 5.3 and 6.4 shows the result of wet sieve analysis and plummet balance test respectively. Fig. 5.1 shows that the combined grin size distribution curve obtained after dry sieve, wet sieve analysis and plummet balance method.

5.1.2 Wet sieve analysis

Mass of total soil taken for analysis = 400 gm

% of soil sample passing 4.75 mm sieve = 95.8%

Mass of soil taken for this analysis = 200 gm.

Table 5.2 wet sieve analysis

IS sieve	Wt. Retained (gm)	% retained	Cumulative % retained	% finer
2.000	0.10	0.05	0.05	99.95
1.000	0.80	0.40	0.45	99.95
0.600	5.10	2.55	3.00	97.00
0.425	6.60	3.30	6.30	93.70
0.300	4.60	2.30	8.60	91.40
0.212	2.60	1.30	9.90	90.10
0.150	9.20	4.60	14.50	85.50
0.075	38.30	19.15	33.65	66.35
pan	9.60	4.80	-	-

5.1.3 Plummet balance test

Temperature (T) = 31.5°C

Specific gravity = 2.62

Effective length (Z_e) =15.1 cm

Mean diameter (d) 26.55 − 21.48 = 5.07% Where t = time in minute

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Table 5.3. Result of plummet balance analysis

Sl. no	Time t, minute	Mean diameter, d (mm)	% finer
1	1	0.047	53
2	2	0.033	34
3	3	0.027	21
4	4	0.024	13
5	5	0.021	8
6	6	0.019	5

Table 5.4 combined grain sieve analysis of the soil sample

Sl. no.	Diameter (mm)	% finer than
1	100.000	100.0
2	75.000	100.0
3	19.000	100.0
4	4.750	95.8
5	2.000	100.0
6	1.000	100.0
7	0.600	97.0
8	0.425	93.7
9	0.300	91.4
10	0.212	90.1
11	0.150	85.5
12	0.075	66.4
13	0.047	53.0
14	0.033	34.0
15	0.027	21.0
16	0.024	13.0
17	0.021	8.0
18	0.019	5.0

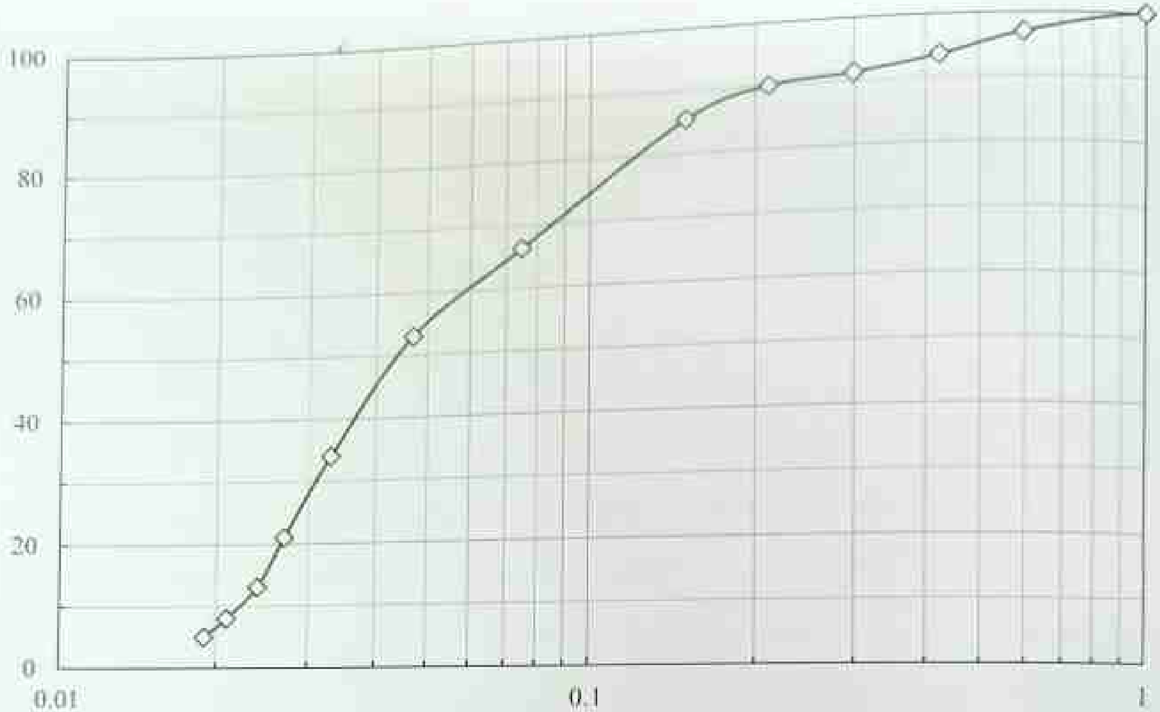

Fig. 5.1. Grain size distribution curve of soil sample

5.2. Liquid Limit and plastic limit test

Table 5.5 and 5.6 shows the result of liquid limit and plastic limit test. Plasticity index obtained from liquid limit and plastic limit test was 5.07. Based on the observed liquid limit and plastic

Table 5.5. Result of liquid limit test

Determination no.	1	2	3	4	5
No of blows (n)	38	30	22	13	12
Container no.	1	2	3	4	5
Mass of container+ wet soil, (gm)	49.00	41.00	39.00	47.00	47.00
Mass of container + dry soil, (gm)	43.20	35.12	32.50	40.25	40.15
Mass of water, (gm)	5.81	5.88	6.51	6.75	6.85
Mass of container, (gm)	19.00	11.00	9.00	17.00	17.00
Mass of dry soil, (gm)	24.20	24.12	23.50	23.25	23.15
Moisture content,%	23.97	24.38	27.66	29.03	29.59

limit values, the sample soil was classified as CL-ML as per plasticity chart (Indian standard soil classification system)

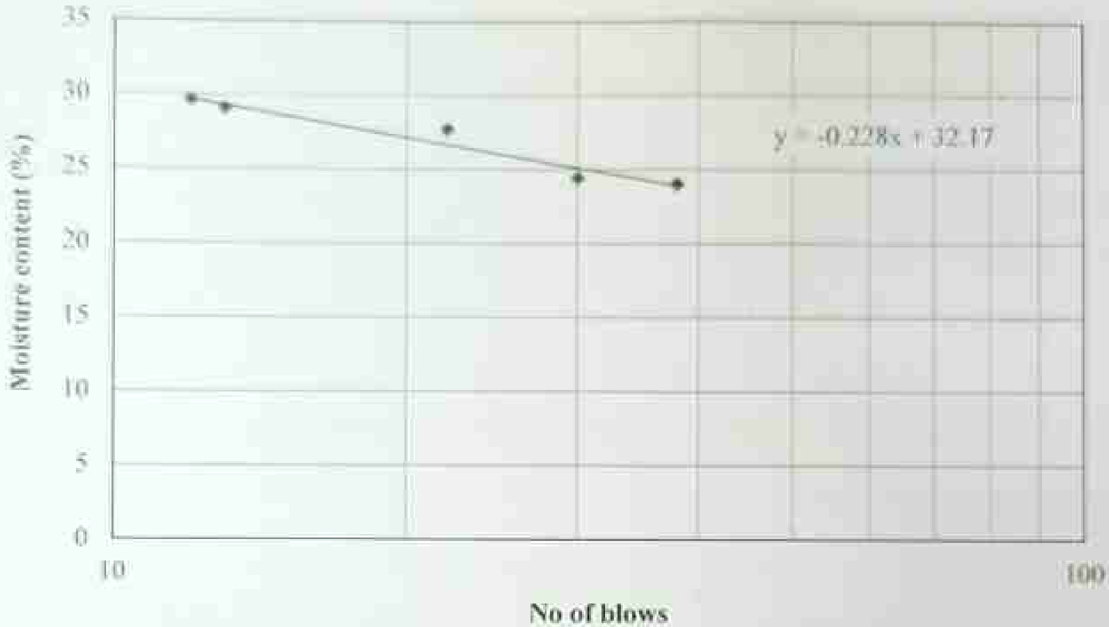

Fig. 5.2. Liquid limit curve

From the Fig. 5.2, the liquid limit (LL) of the sample soil obtained was 26.55%.

Table 5.6. Result of plastic limit test

Determination no.	**1**	**2**	**3**
Container no.	1	2	3
Mass of container + wet soil, (gm)	22.82	13.82	17.21
Mass of container + dry soil, (gm)	19.96	11.99	18.25
Mass of water, (gm)	0.42	0.32	0.23
Mass of container, (gm)	20.10	12.08	17.27
Mass of dry soil, (gm)	2.30	1.42	0.98
Plastic limit, %	20.44	22.32	21.70

Average plastic limit (PL) = 21.48%

Plasticity index (PI) = 26.55−21.48 = 5.07%

5.3. Specific gravity test

Table 5.7 shows the result of specific gravity test carried out on 3 soil sample. The average specific gravity of the soil sample was obtained 2.62.

Test temperature T = 31° C

Relative density of water at T° C = 0.995369

Relative density of water at 27° C =0.996542

Table 5.7. Result of specific gravity test

Determination number	**1**	**2**	**3**
Pycnometer number	1	2	3
Mass of pycnometer, W_1 (gm)	24.83	24.83	24.83
Mass of pycnometer + dry soil, W_2 (gm)	47.03	38.70	46.36
Mass of pycnometer + soil + water, W_3 (gm)	90.55	85.44	90.07
Mass of pycnometer + water, W_4 (gm)	76.82	76.82	76.82
Specific gravity of soil at T_1	2.62	2.64	2.60
Specific gravity of soil at 27°C	2.61	2.64	2.60

Average specific gravity of the sample soil obtained was = 2.62

5.4. Proctor test of soil

Table 5.8 shows the result of proctor test carried out on soil sample. The MDD and OMC of the

Table 5.8. Proctor test of soil sample

s. no.	Moisture content (%)	weight of mould + base plate (kg)	weight of wet soil, W (kg)	bulk density, γ_t (g/cc)	dry density $\gamma_d = \gamma_t /(1+ m/100)$ g/cc
1	9.4	14.975	4.339	1.928	1.763
2	13.8	15.286	4.650	2.067	1.832
3	16.9	15.428	4.792	2.130	1.822
4	21.2	15.274	4.638	2.061	1.701
5	25.3	15.14	[illegible]	2.002	1.598

soil sample obtained from the test were 1.83 gm/cc and 14% respectively. Fig. 5.3 shows the compaction curve obtained from the proctor test.

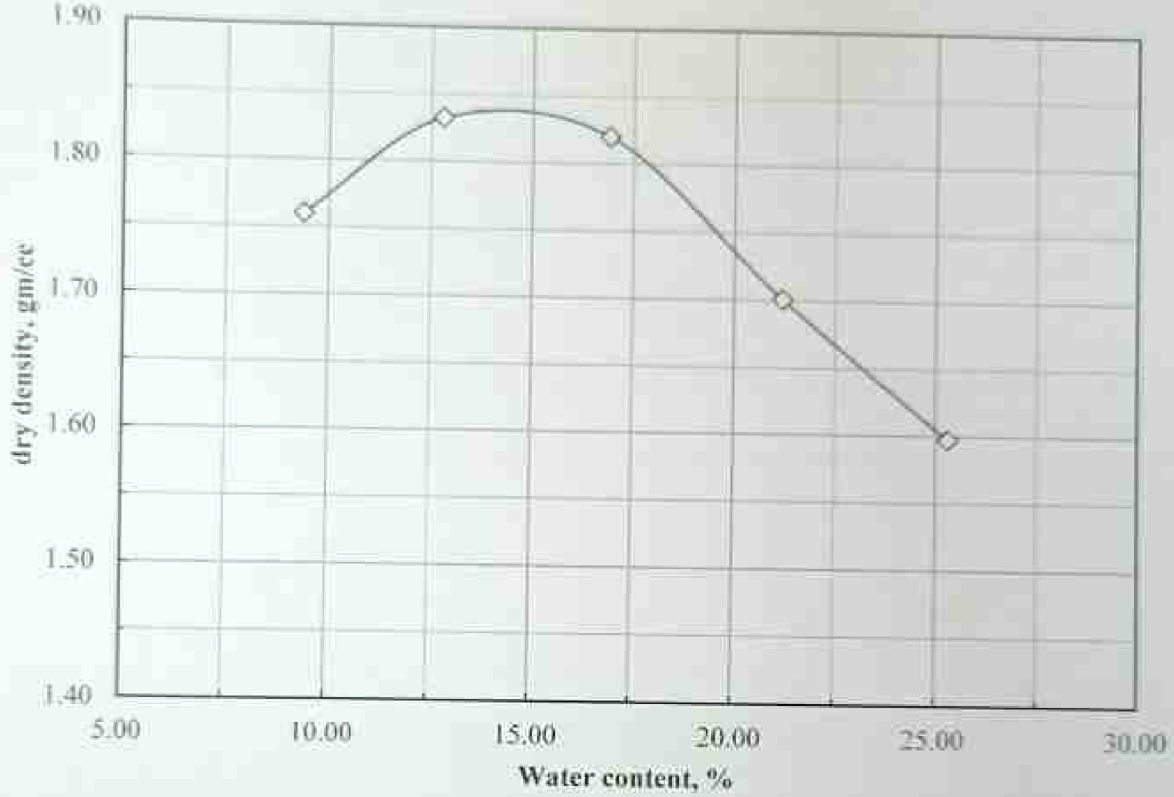

Fig. 5.3. Proctor test of soil sample

5.5. California bearing ratio (CBR) test of soil

Table 5.9 and 5.10 show the result of CBR test for unsoaked and soaked condition. At unsoaked condition, the CBR value obtained was 12.3% whereas, at soaked condition, it was 10.1%. Fig. 5.4 and 5.5 show the load vs penetration curve obtained from the CBR test.

Table 5.9. California bearing ratio test on soil

Penetration (in mm)	load (in kN)	Penetration (in mm)	load (in kN)
0.5	0	7	2.96
1	0.34	7.5	3.12
1.5	.069	8	3.35
2	1.03	8.5	3.56
2.5	1.42	9	3.75
3	1.68	9.5	3.96
3.5	1.89	10	4.13
4	2.05	10.5	4.35
4.5	2.12	11	4.56
5	2.29	11.5	4.75
5.5	2.42	12	4.96
6	2.62	12.5	5.12
6.5	2.82	13	5.36

Fig. 5.4. Load penetration curve of soil sample under unsoaked condition

Unsoaked CBR value of soil sample = $1.68 \times 10000/1370 = 12.3\%$

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Table 5.10. California bearing ratio for soaked sample

penetration (in mm)	load (in kN)	penetration (in mm)	load (in kN)
0.5	0	7	2.43
1	0.28	7.5	2.56
1.5	0.57	8	2.75
2	0.85	8.5	2.92
2.5	1.17	9	3.08
3	1.38	9.5	3.25
3.5	1.55	10	3.39
4	1.68	10.5	3.57
4.5	1.74	11	3.74
5	1.88	11.5	3.90
5.5	1.99	12	4.07
6	2.15	12.5	4.20
6.5	2.32	13	4.40

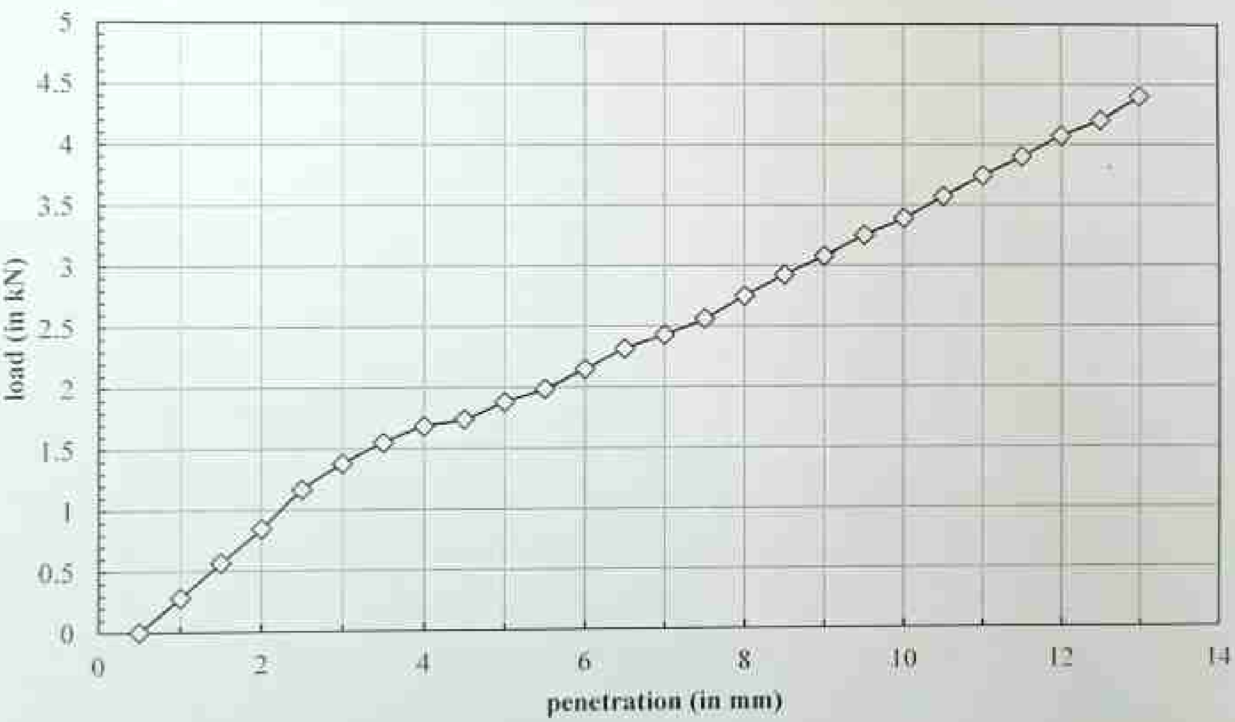

Fig. 5.5. Load penetration curve of soil sample under soaked condition

Soaked CBR value of soil sample = 1.38 × 10000/1370=10.1%

5.6. Sieve analysis of e-waste

Table 5.11 shows the result of sieve analysis carried out on shredded e-waste. The result of sieve analysis shows that the manually shredded e-waste have size above 2mm. Fig. 5.6 shows the particle size distribution curve of shredded e-waste plastic.

Table 5.11. sieve analysis of e-waste

IS sieve size	Wt. on each sieve	cumulative retained	cumulative % retained	% passing
75	0	0	0	100
53	30	30	3.00	97.00
20	70	100	9.99	90.01
10	431	531	53.05	46.95
4.75	267	798	79.72	20.28
2	130	928	92.71	7.29
0.425	73	1001	100	0
0.075	0	1001	100	0

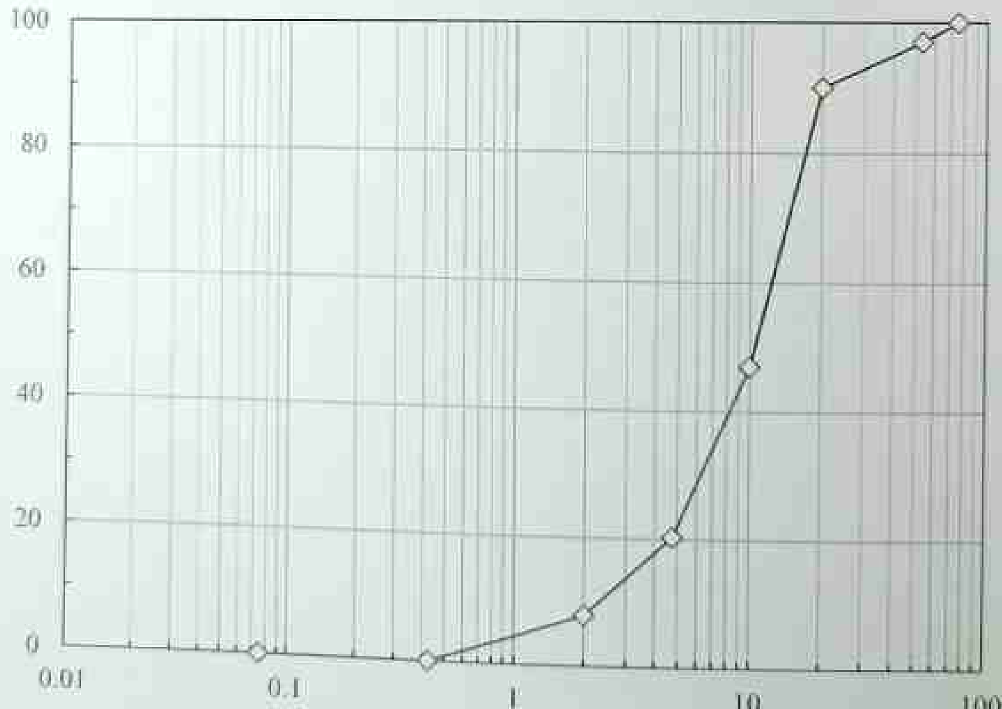

Fig. 5.6. sieve analysis of e-waste

5.7. Specific gravity of e-waste

Specific gravity of e-waste was determined using pycnometer. Table 5.12 shows the result of specific gravity of e-waste. The average specific gravity of e-waste obtained from the test was 1.92.

Table 5.12. result of specific gravity of e-waste

mass of pycnometer, w1 (g)	mass of pycnometer + dry soil,w2 (g)	mass of pycnometer +dry soil + water, w3 (g)	mass of pycnometer + water,w4 (g)	specific gravity (g/cc)
52.4	64.50	133.86	152.3	1.91
52.3	68.70	127.21	152.2	1.92
52.4	72.45	121.75	152.3	1.93

5.8. Aggregate impact test on e-waste

Weight of e-waste taken, A = 180 g
Weight of e-waste passing 2.35 mm sieve after impact test, B = 22.5 g
Weight of e-waste retained on 2.35 mm sieve after impact test, C = 138.5
Total weight on mould after impact = B + C = 161 g < 180 g
Aggregate impact value = (B/A) × 100 %
= (22.5/180) × 100%
= 12.5%

5.9. Proctor test of e-waste soil mixture

Table 5.13 - 5.16 show the result of proctor test carried out on e-waste soil mixture. Fig. 5.7 - 5.10 show the compaction curve obtained from the proctor test.

Table 5.13. Proctor test on soil with 10% e-waste

s. no.	Moisture content (%)	weight of mould + base plate (kg)	weight of wet soil, W (kg)	bulk density, γ_t g/cc)	dry density $\gamma_d = \gamma_t /(1+ m/100)$ g/cc
1	9.2	14.761	4.181	1.858	1.702
2	12.6	14.984	4.04	1.957	1.738
3	14.7	15.196	4.616	2.052	1.789
4	16.9	15.212	4.632	2.059	1.761
5	20.75	15.196	4.616	2.052	1.699

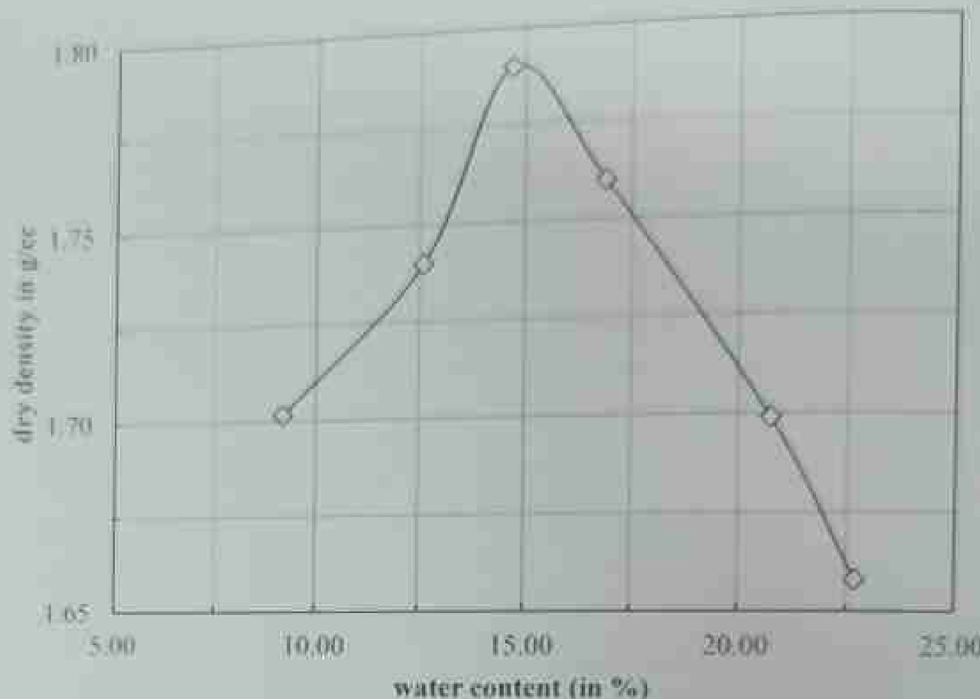

Fig. 5.7. Proctor test on soil with 10% e-waste

Table 5.14. Proctor test on soil with 20% e-waste

S. no.	Moisture content (%)	weight of mould + base plate (kg)	weight of wet soil, W (kg)	bulk density, γ_t (g/cc)	dry density $\gamma_d = \gamma_t / (1+ m/100)$ g/cc
1	10.4	14.602	3.966	1.763	1.597
2	14.5	15.112	4.476	1.989	1.737
3	18.27	15.101	4.465	1.984	1.678
4	22.7	14.805	4.169	1.853	1.510
5	26.2	14.693	4.057	1.803	1.429

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Fig. 5.8. proctor test on soil with 20% e-waste

Table 5.15. Proctor test on soil with 30% e-waste

s. no.	Moisture content (%)	weight of mould + base plate (kg)	weight of wet soil, W (kg)	bulk density, γ_t (g/cc)	dry density $\gamma_d = \gamma_t /(1+m/100)$ g/cc
1	10.3	14.589	3.953	1.757	1.593
2	14.4	15.045	4.409	1.960	1.713
3	17.8	15.154	4.518	2.008	1.704
4	21.7	14.785	4.149	1.844	1.515
5	25.8	14.684	4.048	1.799	1.430

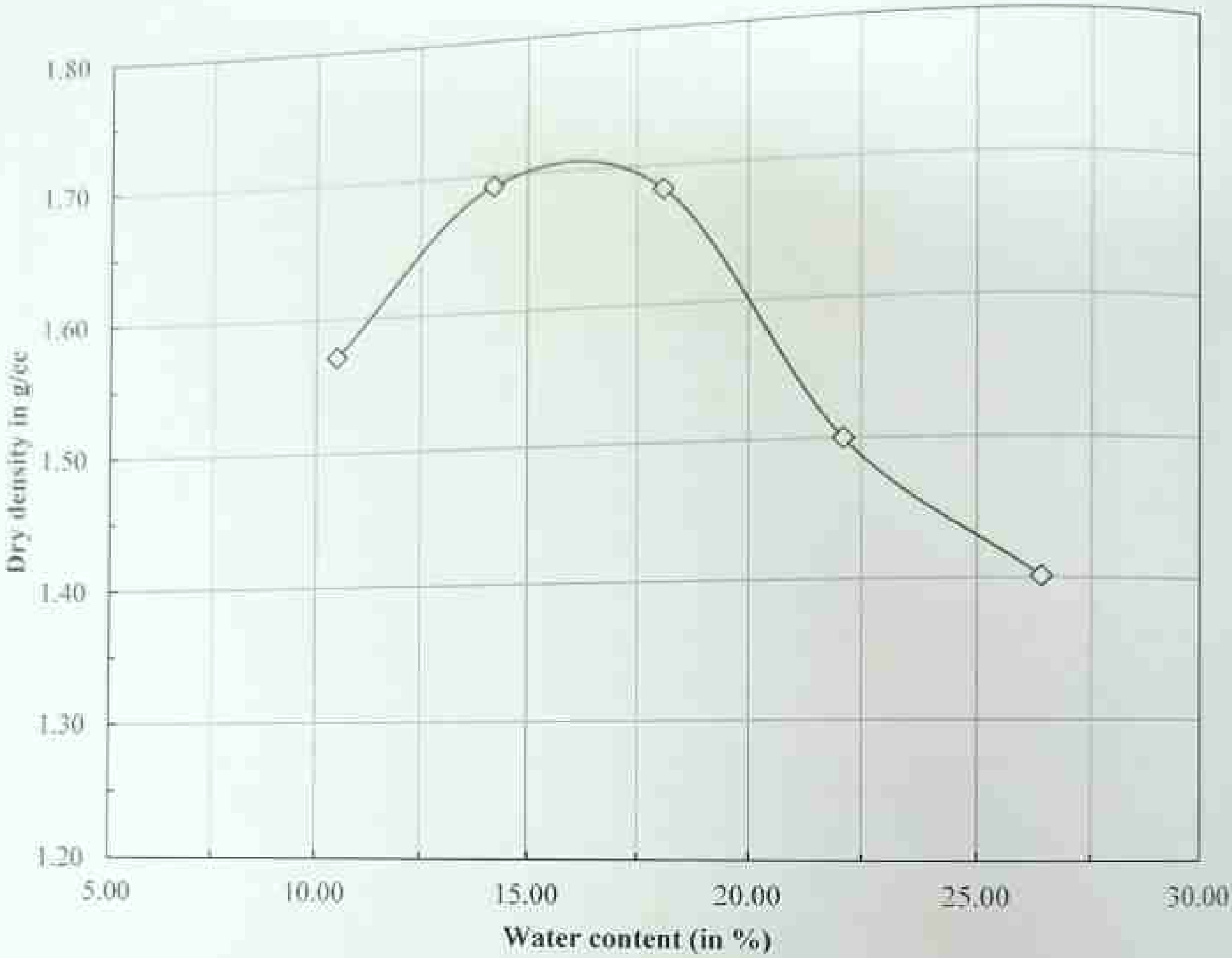

Fig. 5.9. Proctor test on soil with 30% e-waste

Table 5.16. Proctor test on soil with 40% e-waste

s. no.	Moisture content (%)	weight of mould + base plate (kg)	weight of wet soil, W (kg)	bulk density , γ_t (g/cc)	dry density $\gamma_d = \gamma_t /(1+ m/100)$ g/cc
1	10.5	14.542	3.906	1.736	1.571
2	14.2	14.984	4.348	1.932	1.692
3	18.1	15.108	4.472	1.988	1.683
4	22.1	14.756	4.120	1.831	1.500
5	26.4	14.621	3.985	1.771	1.401

Fig. 5.10. Proctor test on soil with 40% e-waste

5.10. CBR test of e-waste soil mixture

Table 5.17 - 5.20 shows the result of unsoaked CBR test of e-waste soil mixture containing e-waste 10%, 20%, 30% and 40% respectively.

Table 5.17. California bearing ratio test on soil with 10% e-waste

displacement (in mm)	load (in kN)	displacement (in mm)	load (in kN)
0.5	0	7	3.36
1	0.33	7.5	3.56
1.5	0.84	8	3.75
2	1.31	8.5	3.98
2.5	1.65	9	4.12
3	1.89	9.5	4.23
3.5	1.98	10	4.45
4	2.15	10.5	4.69
4.5	2.34	11	4.89
5	2.49	11.5	5.02
5.5	2.65	12	5.19
6	2.98	12.5	5.31
6.5	3.12	13	5.61

California bearing ratio for 10% e-waste in soil = 1.89 × 10000/1370=13.8

Table 5.18. California bearing ratio test on soil with 20% e-waste

displacement (in mm)	load (in kN)	displacement (in mm)	load (in kN)
0.5	0	7	2.71
1	0.23	7.5	2.91
1.5	0.81	8	3.12
2	1.12	8.5	3.34
2.5	1.36	9	3.56
3	1.54	9.5	3.74
3.5	1.75	10	3.94
4	1.89	10.5	4.12
4.5	2.02	11	4.31
5	2.15	11.5	4.56
5.5	2.21	12	4.71
6	2.36	12.5	4.92
6.5	2.59	13	5.03

California bearing ratio for 20% e-waste in soil = 1.54 × 10000/1370=11.3

Table 5.19. California bearing ratio test on soil with 30% e-waste

displacement (in mm)	load (in kN)	displacement (in mm)	load (in kN)
0.5	0	7	2.51
1	0.38	7.5	2.75
1.5	0.86	8	2.96
2	1.13	8.5	3.15
2.5	1.23	9	3.38
3	1.47	9.5	3.56
3.5	1.55	10	3.75
4	1.71	10.5	3.91
4.5	1.89	11	4.12
5	2.02	11.5	4.28
5.5	2.13	12	4.59
6	2.25	12.5	4.79
6.5	2.39	13	4.98

California bearing ratio for 30% e-waste in soil = 1.47 × 10000/1370=10.8

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Table 5.20. California bearing ratio test on soil with 40% e-waste

displacement (in mm)	load (in kN)	displacement (in mm)	load (in kN)
0.5	0	7	2.51
1	0.41	7.5	2.71
1.5	0.75	8	2.93
2	0.98	8.5	3.16
2.5	1.09	9	3.38
3	1.21	9.5	3.52
3.5	1.38	10	3.81
4	1.65	10.5	4.02
4.5	1.72	11	4.32
5	1.81	11.5	4.61
5.5	1.93	12	4.83
6	2.12	12.5	5.06
6.5	2.31	13	5.36

California bearing ratio for 40% e-waste in soil = 1.93 × 10000/2055=9.4

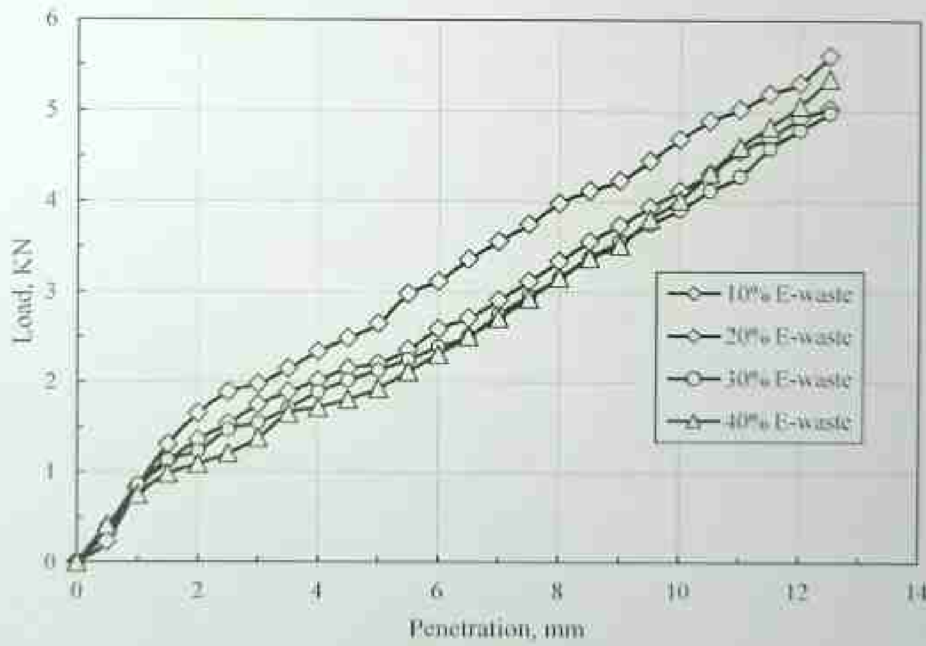

Fig. 5.11. Load penetration curve of e-waste soil mixture for unsoaked condition

Table 5.21 - 6.24 shows the result of soaked CBR test of e-waste soil mixture containing e-waste 10%, 20%, 30% and 40% respectively.

Table 5.21. CBR value for soil with 10% at soaked condition

penetration (in mm)	Load (in kN)	penetration (in mm)	load(in kN)
0.5	0	7	2.99
1	0.29	7.5	3.17
1.5	0.75	8	3.34
2	1.17	8.5	3.54
2.5	1.47	9	3.67
3	1.68	9.5	3.76
3.5	1.76	10	3.96
4	1.91	10.5	4.17
4.5	2.08	11	4.35
5	2.21	11.5	4.47
5.5	2.36	12	4.62
6	2.65	12.5	4.73
6.5	2.78	13	4.99

CBR value for soil with 10% at soaked condition is=1.68 × 10000/1370=12.3

Table 5.22. CBR value for soil with 20% at soaked condition

penetration (in mm)	load (in kN)	penetration (in mm)	load (in kN)
0.5	0	7	2.25
1	0.19	7.5	2.42
1.5	0.67	8	2.59
2	0.93	8.5	2.77
2.5	1.13	9	2.96
3	1.28	9.5	3.10
3.5	1.45	10	3.27
4	1.57	10.5	3.42
4.5	1.68	11	3.58
5	1.78	11.5	3.78
5.5	1.83	12	3.91
6	1.96	12.5	4.08
6.5	2.15	13	4.18

CBR value for soil with 20% at soaked condition is=1.28 × 10000/1370=9.4

Table 5.23. CBR value for soil with 30% at soaked condition

penetration (in mm)	load (in kN)	penetration (in mm)	load (in kN)
0.5	0	7	1.88
1	0.28	7.5	2.06
1.5	0.64	8	2.21
2	0.84	8.5	2.36
2.5	0.92	9	2.53
3	1.10	9.5	2.66
3.5	1.16	10	2.80
4	1.28	10.5	2.92
4.5	1.41	11	3.08
5	1.51	11.5	3.20
5.5	1.59	12	3.43
6	1.68	12.5	3.58
6.5	1.79	13	3.72

CBR value for soil with 30% at soaked condition is=1.10 × 10000/1370=8.1

Table 5.24. CBR value for soil with 40% at soaked condition

penetration (in mm)	load (in kN)	penetration (in mm)	load (in kN)
0.5	0	7	1.30
1	0.21	7.5	1.40
1.5	0.39	8	1.52
2	0.51	8.5	1.64
2.5	0.56	9	1.75
3	0.63	9.5	1.82
3.5	0.71	10	1.97
4	0.86	10.5	2.08
4.5	0.89	11	2.24
5	0.94	11.5	2.39
5.5	1.00	12	2.50
6	1.10	12.5	2.62
6.5	1.20	13	2.78

CBR value for soil with 40% at soaked condition is=1 × 10000/1370=7.3

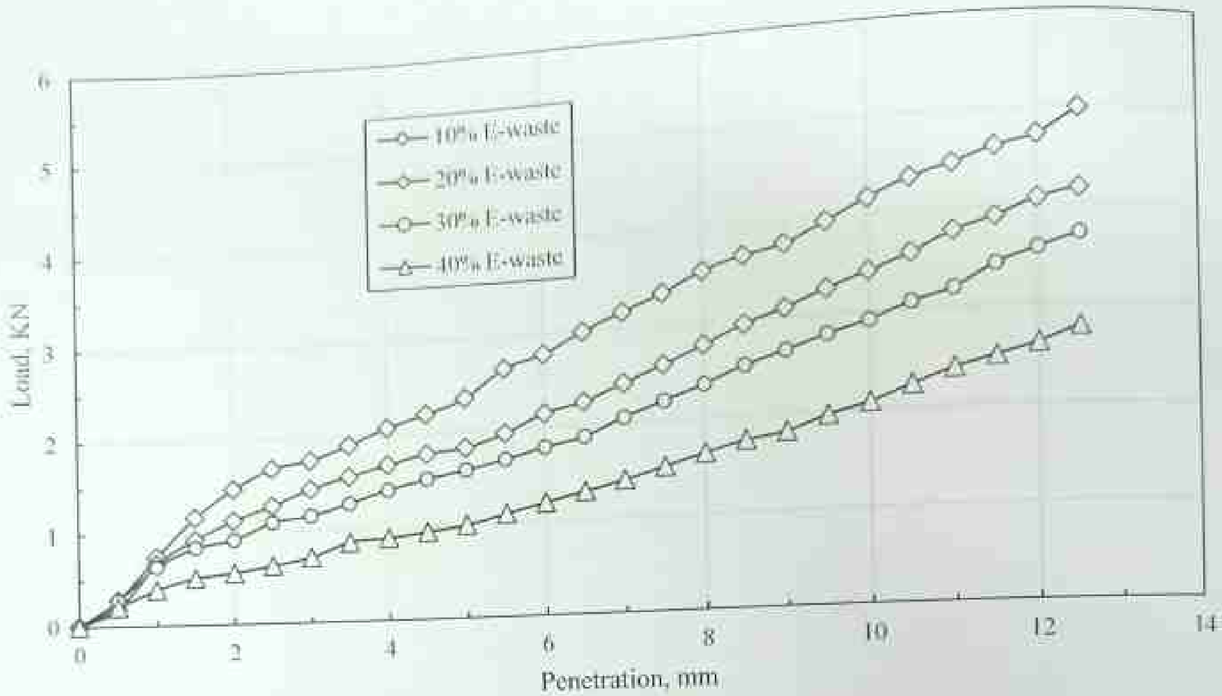

Fig. 5.12. Load penetration curve of e-waste soil mixture for soaked condition

5.11. Direct shear test

The results of direct shear test of soil and e-waste soil mixture is presented in Table 5.25. Shear strength of soil composites increases on adding e-waste. Dispersion of e-waste on mixing with soil increases friction between soil particles, which increases shear strength of the soil composites. However, optimum content of waste material either e-waste could not be assessed from the present study as shear strength of the soil composites was kept on increasing at all the waste content.

Table 5.25. Result of direct shear test

E-waste, %	Shear strength kg/cm^2
0	1.25
10	1.25
20	1.38
30	1.38
40	1.52

5.12. Summary

Table 5.26 shows the result of the CBR value of e-waste soil mixture achieves CBR value more than the normal soil sample. The improvement was found maximum in for 10% e-waste.

However, the improvement was insignificant in case of unsoaked CBR test. The CBR value decreases further beyond the 10% e-waste. It represents that the raising the e-waste content reduces the dry density of soil. Inclusion of e-waste to the soil sample for CBR test eliminates same weight of soil. It reduces the cohesion characteristics of soil. Therefore, unsoaked CBR value reduces beyond 10% e-waste content. Similar phenomenon happens in case soaked CBR test, which showed the reduction beyond 10% e-waste content. However, the improvement in case of soaked CBR value is higher than that of unsaoked one. This may be due to resistance to flow water due to presence of e-waste plastic inside the compacted CBR soil sample. Dry density

Table 5.26. Summary table

Sl. No.	E-waste content, %	Maximum dry density, gm/cc	OMC, %	Unsoaked CBR value, %	Soaked CBR value, %
1	0	1.83	14	12.3	10.3
2	10	1.78	15	13.8	12.3
3	20	1.74	14.5	11.3	9.4
4	30	1.71	14.5	10.8	8.1
5	40	1.69	14	9.4	7.3

of the e-waste soil mixture found to be reducing on increasing e-waste content. This may be attributed to the elimination of the dry soil equal to that of e-waste content. However, optimum water content approximately remains same.

CONCLUSION

Following are the conclusion may be drawn based on the result obtained from the investigation

1. E-waste plastic may be used as soil stabilizing agent to improve the properties of soil necessary for subgrade construction.

2. E-waste soil mixture was found to have lesser maximum dry density compared to the normal soil and the reducing progress with increase of e-waste.

3. E-waste soil mixture was found to optimum moisture content approximately equal to the normal soil.

4. Unsoaked and soaked CBR value of soil increases at e-waste content 10% by weight of dry soil. Further increase of e-waste reduces the CBR value of soil. The reason may the lake of compaction that reduces the maximum dry density of soil. The improvement of CBR value is found to be more in case of soaked condition.

5. Dispersion of e-waste on mixing with soil increases friction between soil particles, which increases shear strength of the soil composites. However, optimum content of waste material either e-waste could not be assessed from the present study as shear strength of the soil composites was kept on increasing at all the waste content.

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