A Project Report on

Subgrade stabilization, Design and Analysis of Flexible Pavement By Mechanistic Empirical Approach

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Bachelor of Engineering

by

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CERTIFICATE

This is to certify that the project entitled **"Subgrade stabilization, Design and Analysis of Flexible Pavement By Mechanistic Empirical Approach "**is a bonafide work of **"Siddique Izhar Ahmed, Sayed Danish Mushir Ahmed and Shah Shahnawaj Bashir"** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Undergraduate" in "Civil Engineering"

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DECLARATION

We declare that this written submission represents my ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that, we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

Soil stabilization is one of most important process in construction of road pavement and foundation because it improves the engineering properties of soil such as strength, volume stability and durability. The disposal of solid waste now –a- days is of major concern. solid waste like fly ash is generated in tonnes every year. Usin large amount of fly ash in pavement construction will bring economy in pavement design. Using fly ash makes it more environment friendly and reduces the disposal actions and it creates an options of recycling.

An attempt is made to use fly ash to stabilized the soil and design the thickness of pavement by MEPGD.

The thickness of flexible pavement on virgin soil is tested, stabilized and designed. Design involves computing the stress and strain by using IIT pave software, In order to achieve the strength which are the major problem in weak soil like clay and try to bring economy in future road constructions.

KEYWORD: Subgrade stabilization, Economical design of flexible pavement.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATION NOTATION AND NOMENCLATURE

IRC Indian road congress

msa million standard axel

CBR California bearing ratio

BC bituminous concrete

DBM Dense bituminous concrete

OMC optimum moisture content

ε_t Horizontal tensile strain

ε_z vertical compressive strain

M_R Resilient modulus

N_f fatigue life in number of standard axel

Chapter 1

Introduction

The project in the following chapters relates to a study on the subgrade stabilization, Design and analysis of flexible pavement by using mechanistic empirical approach.

1.1 General

The swelling and shrinkage characteristics of clay soil depend upon the percentage of moisture content in it. So the clay soil undergoes volumetric changes due to variation of water content in it. The finer particles of soil lead to the water holding capacity. The percentage of moisture content inside the soil depends upon the seasonal variation.

The swellings and shrinkage characteristics of the clay soil causes the differential movement, resulting in severe damaged to the foundation, building, roads, retaining structures, canal lining, etc. The clayey soil losses its chemical strength during the expansive condition.

The fly ash generally produced by combustion of coal of thermal power plant. The large number of power plant has been established across the world to fulfil the demand of power. Fly ash is extracted from flue gases of a furnace fired with coal and is non plastic fine silt. Its composition varies according to nature of coal burned. Many efforts are being directed toward beneficial utilization of this waste product in several ways. Since, fly ash is a waste material from thermal power plant and shows pozzolanic characteristic, it is always encouraged to use fly ash for stabilization where easily and economically available.

Subgrade soil stabilization has proved to be very economical as it provides decrease in thickness of pavement layer.

The subgrade should be sufficiently stable to:

1. Prevent excessive rutting and shoving during construction;

2. Provide good support for placement and compaction of pavement layer;
3. Limit pavement rebound deflections to acceptable limits; and
4. Restrict the development of excessive permanent deformation (rutting) in the subgrade during the service life of the pavement. When the subgrade does not possess these attributes, corrective action in the form of subgrade treatment is needed.

Transportation infrastructure plays a lead role in economic growth and development of country. India has the second largest highway and road network system in the world. Ordinarily the term pavement only means
the surface layer. But in the designing of the highway, it means the pavement total thickness including the wearing course, base course and sub-base course. It is hard and tough crust constructed over natural subgrade in order to provide stable and levelled surface for vehicles. It is a structure consist from overlies layers of material over the natural subgrade which is primary and major function is to transfer and distribute the vehicle axle load to the subgrade.

1.2 Need for present investigation

With the rapid growth of traffic now, the pavement are required to be designed for heavy volume of traffic of the order of 150 million standard axle. Pavement constructed over clays often show premature failure originating from subgrade. This necessitates the attention of civil engineers to investigate into causes of pavement failures arrive at improved into method of design or modify pavement construction technology to suit environment of clay.
So, in India mostly subgrade is modified by using various industrial waste such as fly ash, lime, plastic waste, Portland cement, etc. this are the numbers of products available in market, with which subgrade have been modified.

Thus, in this project we intend to use fly ash in road to stabilize subgrade clayey soil because fly ash is one of the abundant form of solid waste produced at thermal power plant and its disposal is a big problem.

1.3 General information on Fly ash as material:

Fly ash also known as pulverised fuel ash in a coal combustion product that is composed of the particulates (Fine particle of burned fuel) that are driven out of coal-fired together with flue gases. Ash that falls to the bottom of boilers is called bottom ash. Fly ash include substantial amount of silicon dioxide(SiO_2) and aluminium oxide (Al_2O_3) and calcium oxide (CaO).

The minor constituent of fly ash depends upon the specific coal bed composition but may include one or more of the following elementsarsenic, boron, cobalt, lead, etc. In the past, fly ash was generally released into the atmosphere, but air pollution control standards now require that it be captured prior to release by fitting pollution control equipment. In the United States, fly ash is generally stored at coal power plants or placed in landfills. Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify rapidly while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 300 µm.

Fig 1.1 Fly ash

ADVANTAGES OF STABILISATION

• Utilization of local and in situ materials.

• Large number of waste materials can be utilized by increasing theirstrength.

• Re use of soils considered unsuitable.

• Savings in disposal of unsuitable materials.

• Large savings in aggregate consumption.

• Savings in transportation of material.

• Protection of roads (less truck transport)

APPLICATIONS

• Road constructions

• Foundations

• Dams and reservoirs

1.3.1 Fly ash production and consumptions:

Coal-Based power plants consumed ~640 million tonnes of coal by the year end of 2017, which are around three fourths of the total coal used in the country. India's coal is of poor quality with almost 40-45 per cent ash, which means the plants burn 0.74 Kg/KWh of power generation, which is 41 percent higher than the global average.

Fly ash generation, which tuned to ~180 MT by 2017 and with the present momentum of the capacity addition the numbers, will definitely increase to ~221 MT by 2018. Current levels of efforts of ash utilization have resulted in achieving just 56% by year ending 2017 and India is nowhere near its target of utilising 100% of fly ash generated by the coal based power plants.

The industry will be challenged as utilities strive to meet environmental standards. Consequences for coal ash utilization will include a large increase in the amount of FGD gypsum, mercury-laden activated carbons in the fly ash, and a change in fly ash composition as utilities change fuel supplies in response to new environmental controls.

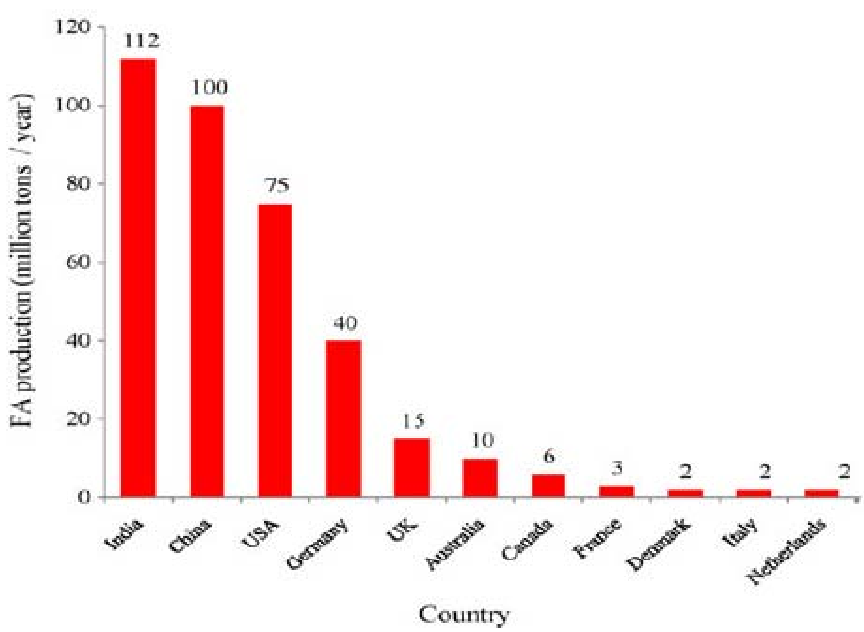

Fig 1.2 - FLY ASH PRODUCTION IN DIFFERENT COUNTRIES (source:- Research Gate)

1.4 Aim and Objective:

- To improves the engineering properties of the soil, eg;
    - Strength – to increase the strength and bearing properties,
    - To reduce pavement thickness as well as overall cost,
    - Durability – to increase the resistance to traffic loading,
    - Volume stability – to control the swell- shrink characteristics caused by moisture changes.
    - To explore the effective usage of fly ash,
    - To study the change in CBR of soil by the addition of fly ash,
    - To study the effect of fly ash and increasing the bearing capacity of soil,
    - Analysis and Evaluation of critical stress and strains using IIT PAVE, Mechanistic based Software with typical axle loads and tyre pressure.
    - Design of new pavement structure based on IRC-37 using CBR of sub grade soil.

1.5 SCOPE OF WORK:

1. The Primary purpose of this study is to analyse the sensitivity of various design parameters which measures sub grade support, traffic load, pavement material properties, environmental factors, performance criteria and its relative effect on design thickness using the Mechanistic Empirical Design guide for the selected stretches mentioned below.
2. The relative importance of these design factors will be determined in this sensitivity analysis study and the impact of changes in input parameter values on the flexible pavement structure will be investigated.

Chapter 2

Literature Review

2.1 General

Basically, highway pavement can be categorized into two group,
flexible and rigid pavement are those which are surfaced with bituminous (or asphalt) materials. These types of pavement are called “flexible” since the total pavement structure is generally composed of several layers of materials which can accommodate this “flexing”. On the other hands rigid pavement composed of a PCC surface course. Such pavements are substantially stiffer than flexible pavements due high modulus of elasticity of the PCC material. Flexible pavement being economical are extensively used as far as possible. A precise engineering design of flexible pavement may save considerable investment; as well as reliable performance of the in-service highway pavement can be achieved.

In recent year, many countries have experienced in increase in truck tyre pressure, axle load and traffic volume. Tyre pressure and axle load increases mean that the bituminous layer near the pavement near the surface is exposed to higher stresses. High density of traffic in terms of commercial vehicle, overloading of truck and significant variations in daily and seasonal temperature of pavements have been responsible for development of distress symptom like ravelling, rutting, cracking, bleeding, shoving and potholing of bituminous surface.

Effective pavement design is one of the more important aspects of project design. The pavement is the portion of the highway which is most obvious to the motorist.

This section deals with different pavement design methodologies of past and present and the important parameters that govern them. Further, this section details some of the case studies done in analysing the sensitivity of flexible pavement to design parameters.

The pavement life is substantially affected by the number of heavy load repetitions applied, such as single, tandem, tridem and quad axle trucks, buses, tractor trailers and equipment. A properly designed pavement structure will take into account the applied loading.
This section deals with different pavement design methodologies of past and present and the important parameters that govern them. Further, this section details some of the case studies done in analysing the sensitivity of flexible pavement to design parameters.

The past years, has been seen a continuing, underlying demand, for higher quality subgrade. As a sequence, modifying additives have been investigated with the aim of improving the properties of the subgrade in road pavements. Some of the modifiers are proprietary product; other are in public domain. Some have been commercially successful; other have not Whatever the fact that there has been such a multiplicity of modifiers can create confusion as to their relative roles and values.

2.2 Review of literature

A review paper on evaluation of flexible pavement failures by author Ashpaq Majeed Naik, Dr. Rakesh Gupta (2010), concluded that various type of failures are causes by fatigue and ratigue and other types of failures resulted from the movement of heavy vehicles, poor drainage design and unsuitable pavement layer thickness layers.

Failure of highway fill and investigation into its causes by author P. Jagannatha Rao(2015) claimed that thickness of highway pavement was of the order of 550 mm. expected life of the pavement was 10 years sever distress including transverse deformation and cracking of the pavement was experienced within one year of traffic started playing on this section.

Pavement Distress: A Case Study by authors Neero Gumsar Sorum, Thangmuansang Guite, Nungleppam Martina according to study conducted, if highway pavement are well designed and constructed they may require proper maintenances; and if not, different distress like fatigue cracking, bleeding, rutting, potholes etc.

Stabilization of expansive soil using fly ash Prof. Pratik sumaiya, Yashwant Zala, Rushikesh Dangar investigate the properties of soil unconfined compressive stress of natural soil without fly ash which was 114KN/m^2,increase to 123KN/m^2 at 20% fly ash in natural soil showing 7.89% improvement

A liquid limit was decrease with increase in percentage of fly ash up 30% in natural soil which was 74.4%,decrease to 72.5%,showing 2.56% decrease.

According to study conducted by Udayashankar D.Hakari, S.C.Puranik on 'Stabilisation of Black Cotton Soils using fly ash'

Based on the result of the investigation following conclusions are ; Addition of fly ash significantly improves the index properties, compaction and strength characteristics of black cotton soils understudy and the effect of fly ash treatment vary depending upon the quantity of fly ash, that mixed with study of black cotton soil sample.

Karthik.S, Ashok Kumar,Gowtham.p,Gokul.D claimed that The borrow red soil bearing capacity of 10 kg/mm2.Stabilize red soil with 6% of fly ash achieve bearing capacity of 35 kg/mm2.CBR value of borrow soil is 3.1. and stabilize CBR value is 4.82.

Fatigue and Rutting lives in flexible pavement as per Ahmed Ebrahim Abu El-Maaty Behiry is Fatigue and rutting lives decreases dramatically with increasing the axle load, especially after the axle load exceed 150KN for fatigue life and 120KN for rutting life.

Stress absorbing membrane interface in the structure is provide to reduce the tensile stress in the bituminous layer and hence "absorb" stress and delays the propagation of crack. By author Harish G R while using IIT PAVE in design of flexible pavement.

According to authors Wael Alkasawneh, P.E., Ernie PanFeng Han, Roanghua Zhu. On publish paper title 'Elastic modulus variation with depth' conclude that in the AC layer the continuous variation of the modulus can reduce the "jump" in the stress and strain between two side interface.

In un soaked California bearing ratio(CBR) test of soil conduct with varying fly ash content, the CBR increase gradually with the increase in fly ash content till its valuation was 20% by weight of the total mixture; it decrease thereafter in Stabilization of expansive soil using fly ash by author Manmay kumar moh

2.3 GAPS AND FINDINGS

Following observations have been pulled out from the broad overview of the literature presented in this chapter:

i) Extensive research work is reported on use of oriented and randomly oriented fibre reinforcements using laboratory testing, while this brought out the positive improvement of geotechnical behaviour of soils. Yet little work reports on the usage of waste fly ash materials.

ii) The majority of works carried out in the area of sub-base or base improvements of the diverse types of pavements using ASH to control erosion and watershed management. Just a few works have been reported involving the utilisation of FA for the advance of engineering properties of land. Consequently, a scope of systematic research study in this field is lacking

2.4 SUMMARY

The review of literature indicate that FA is a versatile material with attractive properties and advantages, as a result of this FA is now being used widely all over the world to stabilise the soil.

Chapter 3

MATERIAL AND METHODOLOGY

3.1 MATERIALS

3.1.1 FLY ASH

Fly ash or flue ash, also known as pulverised fuel ash. It is a coal combustion product that is composed of the particulates that are driven out of coal-fired boilers together with the flue gases. Ash that falls to the bottom of the boiler is called bottom ash.
fly ash is generally captured by electrostaticprecipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottomash removed from the bottom of the boiler, it is known as **coal ash.**

Types of Fly ash

- ✓ Class F
- ✓ Class c

Class F: The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 7% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime—mixed with water to react and produce cementitious compounds.

Class C: Fly ash produced from the burning of younger lignite or sub-bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash hardens and gets stronger over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulphate (SO_4) contents are generally higher in Class

C fly ashes

3.1.2 Benefits of fly ash

Fly ash can be a cost-effective substitute for Portland cement in many markets. Fly ash is also recognized as an environmentally friendly material because it is a by product and has low embodied energy, the measure of how much energy is consumed in producing and shipping a building material. By contrast, Portland cement has a very high embodied energy because its production requires a great deal of heat. Fly ash requires less water than Portlandcement and is easier to use in cold weather.

3.1.3 Properties of fly ash

Table no 3.1 Chemical composition of fly ash

Constituents	Percentage (%)
Silica (Si O2)	57.00
Alumina (Al2 O3)	23.00
Ferric oxide (Fe2 O3)	8.32
Calcium oxide (CaO)	2.70
Magnesium oxide(MgO)	0.83
Titanium Oxide (Ti O2)	0.23
Loss on ignition	7.92

3.2 Methodology

The present investigation aimed at the laboratory evaluation of clay soil to increase the strength of the soil so that CBR value will be enhance for getting the design thickness less.

- **PART A**
  - Stabilization of clayey soil with fly ash variation from 15 % to 45 %
    - ✓ Laboratory test conducted are as follow:
      - Specific gravity,
      - Atterberg limit,
      - Standard proctor test,
      - CBR test.
- **PART B**
  - Design of pavement using IRC 37: 2012
    - ✓ Calculating the cumulative standard axle.
    - ✓ Computing the pavement thickness from IRC 37:2012.
    - ✓ Computing the permissible strain from the IRC 37:2012.
    - ✓ Computing the Actual strain from IITPAVE Software.

- ✓ Analysing all the strain acting on pavement using IITPAVE.

3.1.1 PART A

MATERIAL AND APPARATUS

Clayey soil, fly ash,pycnometer, Casagrande Apparatus, CBR test machine.

Laboratory Testing for basic properties of materials

- **SPECIFIC GRAVITY**
- **ATTERBERG LIMIT**
- **STANDARD PROCTOR TEST**
- **CBR TEST**

Specific gravity

The major measuring equipment in this test is Pycnometer. This is a glass jar of 1 litre capacity that is fitted at its top by a conical cap made of brass. It has a screw type

cover as shown in figure.Figure 3.1

There is a small hole at its apex of 6mm diameter. The leakage is prevented by having a washer between the cap and the jar. While closing the jar, it is screwed till the mark so that the volume of the pycnometer will remain constant throughout the calculation.

Procedure for Specific Gravity of Soil by Pycnometer Method

1. Clean and dry the Pycnometer. Tightly screw its cap. Take its mass (M_1) to the nearest of 0.1 g

2. Mark the cap and Pycnometer with a vertical line parallel to the axis of the Pycnometer to ensure that the cap is screwed to the same mark each time.

3. Unscrew the cap and place about 200 g of oven dried soil in the Pycnometer. Screw the cap. Determine the mass (M_2).

4. Unscrew the cap and add sufficient amount of de-aired water to the Pycnometer so as to cover the soil. Screw on the cap.

5. Shake well the contents. Connect the Pycnometer to a vacuum pump to remove the entrapped air, for about 20 minutes for fine-grained soils and about 10 minutes for coarse-grained soils.

6. Disconnect the vacuum pump. Fill the Pycnometer with water, about three-fourths full. Reapply the vacuum for about 5min till air bubbles stop appearing on the surface of the water.

7. Fill the Pycnometer with water completely upto the mark. Dry it from outside. Take its mass (M_3).

8. Record the temperature of contents.

9. Empty the Pycnometer. Clean it and wipe it dry.

10. Fill the Pycnometer with water only. Screw on the cap upto the mark. Wipe it dry. Take its mass (M_4).

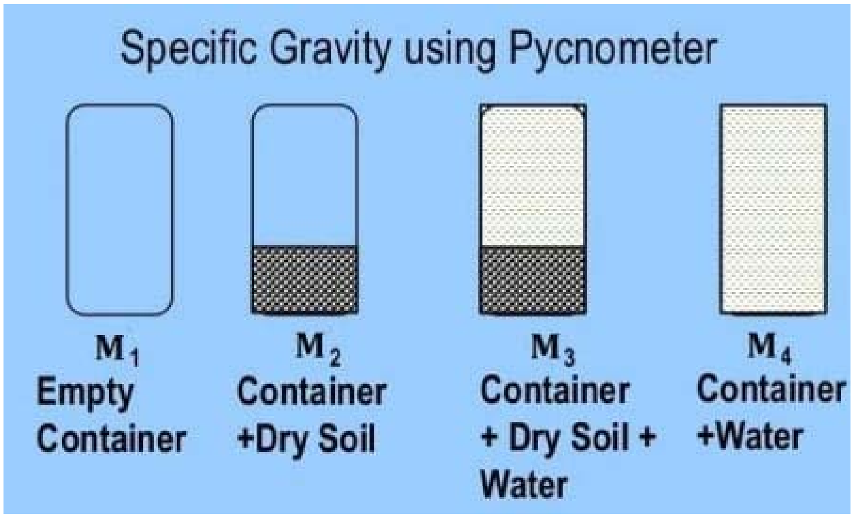

Figure 3.2 Specific Gravity of Soil By Pycnometer Method

Observations and Calculations for Specific Gravity of Soil

The specific gravity of soil is determined using the relation:

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

Where M_1=mass of empty Pycnometer,

M_2= mass of the Pycnometer with dry soil

M_3= mass of the Pycnometer and soil and water,

M_4 = mass of Pycnometer filled with water only.

G= Specific gravity of soils.