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Application of Industrial Waste Iron Sludge for Subgrade Soil Stabilization-A Case Study of Bagodara-Dhandhuka Highway, Gujrat.

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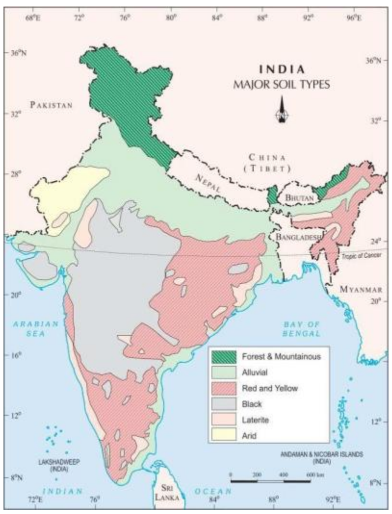
Abstract- *Expansive soil have tremendous strength but it become very soft when it getting wet, it expands/swell due to its mineralogical composition during its wet condition. It creates cracks or consolidated when it is dry. The stability and performance of the pavements are greatly influenced by the sub grade and embankment as they serve as foundations for pavements. Expansive soils can be found on almost all the continents on the Earth. Destructive results caused by this type of soils have been reported in many countries. In India, large tracts are covered by expansive soils known as black cotton soils. These soils cover an area of about 200,000 square miles and thus form about 20% of the total area of India.*

Expansion influences pavement failure due to failure in sub grade so it is required to detail study on stabilization of black cotton soil. Different techniques using different material is available for black cotton soil. Here with attempt is made to suggest suited material or technique required after test results of virgin soil and data collection. The Aim of this paper is to Stabilize Expansive soil of Sub Grade and to improve its properties using Industrial Waste materials.

1. INTRODUCTION

Generally, lands with black cotton soils are fertile and very good for agriculture, horticulture, sericulture and aquaculture. Black cotton soils are very good for agricultural purposes but they are not so good for laying durable roads. Good road network is a basic requirement for the all-round development of an area. Unfortunately, poor road network is hampering the full- fledged development. Expansive soil is one among the problematic soils that has a high potential for shrinking or swelling due to change of moisture content. Expansive soils can be found on almost all the continents on the Earth. Destructive results caused by this type of soils have been reported in many countries. In India, large tracts are covered by expansive soils known as black cotton soils. The major area of their occurrence is the south Vindhyachal range covering almost the entire Deccan Plateau. These soils cover an area of about 200,000 square miles, forming about 20 % of the total area of India. Deccan lava in major parts of Maharashtra, western MadhyaPrades (Hoshangabad, Narsinghpur, Damoh, Jabalpur, Raisen and Shahdol districts), Gujarat (Bhavnagar, Surat, Bharuch, Vadodara, Kheda, Sabarkantha and Dang districts), Andhra Pradesh (Adilabad, Warangal, Khammam, Mahbubnagar, Kurnool, Guntur and Karimnagar districts), Karnataka (Bijapur, Dharwar, Gulbarga, Bidar, Belgaum, Raichur, Bellari and Chitradurga districts), Rajasthan (Kota, Bundi, Sawai Madhopur, Bharatpur and Banswara districts), Tamil Nadu (Ramnathpuram, Tirunelvelli, Coimbatore, Madurai and South Arcot districts) and Uttar Pradesh (Jalaun, Hamirpur, Banda and Jhansi districts).



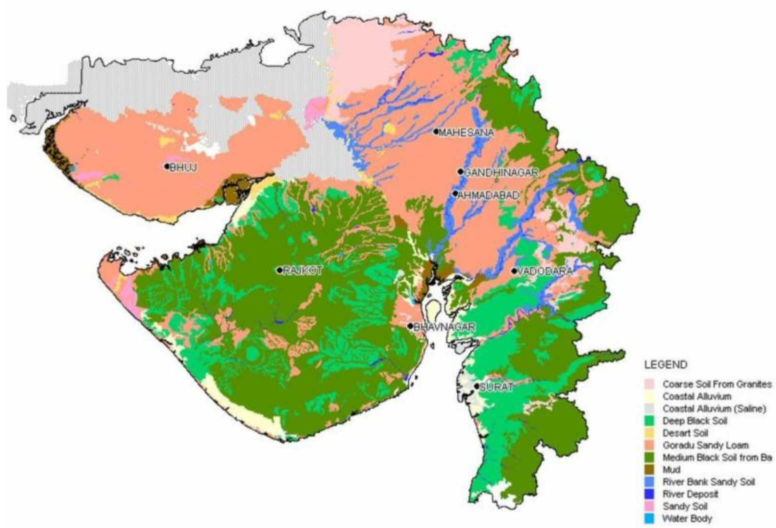


Fig.1 Soil Distribution Map in India **Fig. 2 Soil Distribution Map of Gujarat**

The primary problem that arises with regard to expansive soils is that deformations are significantly greater than the elastic deformations and they cannot be predicted by the classical elastic or plastic theory. Movement is usually in an uneven pattern and of such a magnitude to cause extensive damage to the structures resting on them. Proper remedial measures are to be adopted to modify the soil or to reduce its detrimental effects if expansive soils are identified in a project. Many stabilization techniques are in practice for improving the expansive soils in which the characteristics of the soils are altered or the problematic soils are removed and replaced which can be used alone or in conjunction with specific design alternatives. The characteristics that are of concern to the design engineers are permeability, compressibility and durability. The effect of the additives and the optimum amount of additives to be used are dependent mainly on the mineralogical composition of the soils. Along with improvement in engineering properties of soil, the stabilization is also used to achieve economy in terms of cost by reducing thickness of different layers of pavement. The project can be made more economically viable by using particular stabilization technique for a particular type of soil. Roads are having different layers which provide strength for sustaining the heavy loads due to vehicular movement. Among these, sub grade is the most important one as it provides support to all the above layers. Sub grade is nothing but the natural soil and different types of soil are having different properties. If sub grade soil has poor properties, it needs modification or stabilization to improve its properties. Aim of the research paper are to Stabilized the Expansive soil using Industrial waste, To Study the effect of addition of Industrial waste in soil parameters improvement for subgrade, To check the economic feasibility for use of Industrial Waste. A. Kavak et.al. have found that CBR value increases with increases in percentage of GGBS that show the densification of soil takes place and more suitable for pavement thickness. Effect of Stabilization Using GGBS on Engineering Properties of Black Cotton Soil.

2. STUDY AREA:

Bagodara-Dhandhuka Highway which is State Highway No–1 (61/400 to 105/000) of Gujarat and which is connecting road to NH- 8 E. It covers National Highway – 8E at Bhavnagar. It connects Bagodra-Dhandhuka. The Ahmedabad - Dholera industrial region lies within 100 km from the Dedicated Freight Corridor (DFC) in Central Gujarat. Traffic to Alang braking ship yard which is Asia's largest ship yard is connected to this Highway. Pipavav port is connected with his Highway. For the military and navy purpose this Coastal Highway is very important. Connecting road to Kalpsar Project for sweet water.

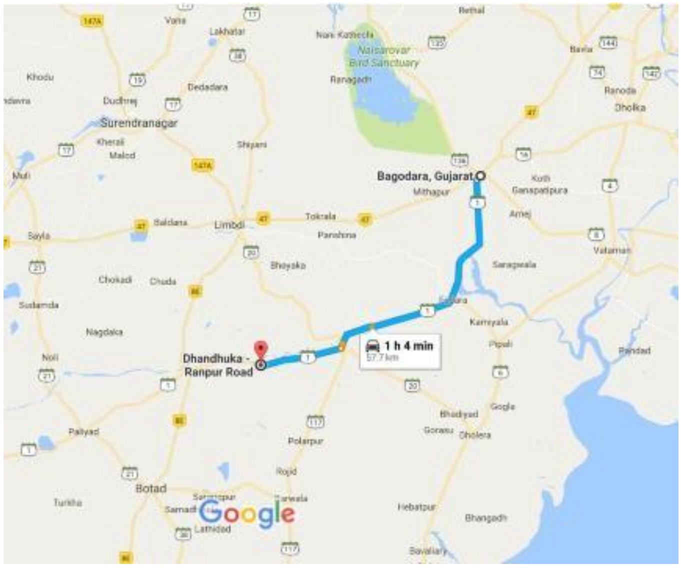


Fig.3 Layout of Study Area (Source: Google Map)

Following problems are seen in study area swelling of soil in subgrade in expansive type of soil. Shrinkage creates crakes in subgrade in dry session. Consolidation creates uneven pavement in dry session. Heavy traffic of multi-axle vehicles due to Pipavav port, Alang Ship Yard, Connecting road to NH-8E at Bhavnagar, Short Route for Ahmedabad, Proposed Kalpsar Project and Dahej Ferry Service. For the purpose of Navy and military it may not allowed to close this highway for a single day also.

3. METHODOLOGY:

Following methodology is adopted for analysis purpose.

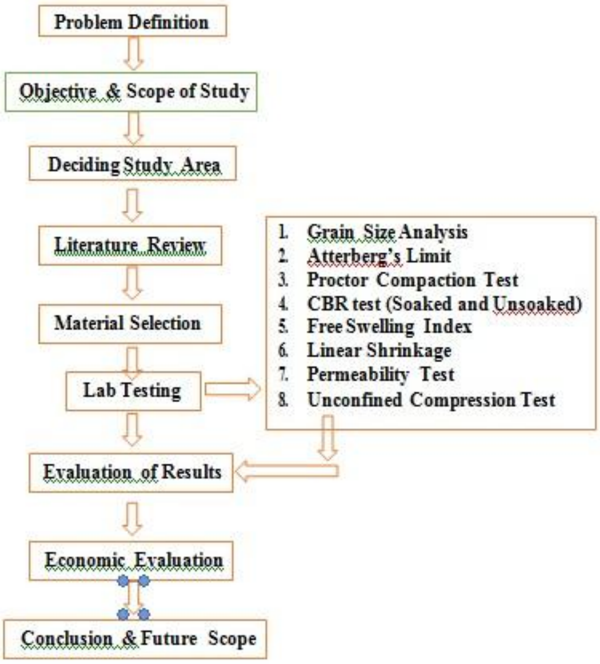


Fig. 4 Flow Chart of Methodology

After Defining Problem of Study Area Laboratory work is required. In Laboratory Work step test on natural and modified soil will carry out. Test required for natural Soil. Grain Size Distribution, Sieve Analysis, Atterberg's Limit, Proctor Compaction Test, California Bearing, Ratio Test (Unsoaked and Soaked), Free Swell Index, Linear Shrinkage, Permeability Test, Unconfined Compression Test. Following test required for treated/modified soil after selection of proper material Atterberg's Limit, Proctor Compaction Test, California Bearing Ratio Test (Unsoaked and Soaked), Free Swell Index, Linear Shrinkage, Permeability Test and Unconfined Compression Test.

Selection of method for stabilization:

Soil stabilization methods are Sand replacement method, Sand Cushion method, Cohesive Non swelling method, Mechanical stabilization.

From detailed study of Expansive soil author have decide to use Industrial waste Iron Sludge for Improvement in soil properties and stabilize the Expansive Soil. Expansive Soil and Case study area have two major issues in sub grade one is low California Bearing ratio value and second is high swelling and high shrinkage. So in this paper work major key contents are to improve those properties and stabilize the soil. From studying literature author have decide to improve soil properties using Industrial Waste product **Iron Sludge**. Iron Sludge is generated by Pharmaceutical Industry.

Fig.-5 Wet Iron Sludge

Fig.-6 Dry Iron Sludge Dump How Iron

As seen from fig.-5 the industrial iron sludge generated after some chemical processes. This sludge is in wet state. After storage for 10-15 days, it becomes dry. For 1 ton of finished product 0.7 ton Iron Sludge is generate. As seen from fig. 6, large quantity of waste is produced is a problem faced by the industry. They sent it to the solid waste disposal site for disposal. Fe is used as catalyst in reduction process; In this process Fe being Oxidize. Initially Fe is in zero valence (Fe^{0}) and after the process it convert into +3 valence (Fe^{+3}). Fe^{+3} is in Pure Powder Form. When it contact with moisture it converts into Fe(OH)3, known as Iron Sludge. Fe(OH)3 is Relative stable, settable with higher density and insoluble in water. Because of higher density it may not be used in concrete but can be used in Sub grade to improve the stability. Iron Sludge has following properties as per the Hazardous waste/Chemical analysis report having Lab. Reg. No. HAZ-293-1999 of ALPHA METAL INDUSTRIES PLOT No. 1216/14 Phase No. 4 NARODA G.I.D.C. City: Ahmedabad; Having Solid Physical State from sludge storage area.

4. ANALYSIS OF LABORATORY TEST:

Linear Shrinkage method covers the determination of the linear shrinkage of remoulded soils. It contains two plate knives, Flat glass plate, Oven, Callipers, Mould (12979) Grease Apparatus. A soil sample weighing about 150 g from the thoroughly mixed portion of the material passing 425 micron (Part1):1985] obtained in accordance with IS 2720 (Part 1) 1983 shall be taken for the test specimen.

Table 1: Laboratory test

Sr. No.	Test Name	Percentage Increase
1	Liquid Limit	6.7
2	Plasticity Index	33.14
3	Optimum Moisture Content	22.36
4	Maximum Dry Density	6.28
5	Free Swell Index	33
6	Unsoaked CBR	120
7	Soaked CBR	98.61
8	Permeability value	8769
9	Linear Shrinkage	31.56
10	Unconfined Compression Strength	90.50

The procedure is adopted to test specimen, About 150 g of the soil sample passing 425 micron IS Sieve shall be placed on the flat glass plate and thoroughly mixed with distilled water, using the palette knives, until the mass becomes a smooth homogeneous paste, with a moisture content approximately 2 percent above the liquid limit of the soil In the case of clayey soils, the soil paste shall be left to stand for a sufficient time (24 h) to allow the moisture to permeate throughout the soil mass. The thoroughly mixed soil-water paste shall be placed in the mould such that it is slightly proud of the sides of the mould. The mould shall then be gently jarred to remove any air pockets in the paste. The soil shall then be levelled off along the top of the mould with the palette knife. The mould shall be placed so that the soil-water mixture (paste) can air. Dry slowly, until the soil has shrunk away from the walls of the mould. Drying should then be completed first at a temperature of 60 to 65°C until shrinkage has largely ceased and then at 105 to 110°C to complete the drying. The mould and soil shall then be cooled and the mean length of soil bar measured if the specimen has become curved during drying. The measurement should be made along the mean arc.

Linear shrinkage = [1- length of Oven Dried Specimen/Initial Length of Specimen]*100

Permeability Value

After Finding the Optimum mix value the permeability test was carried out for natural soil and 20 percentage treated soil.

Permeability Value

Sr. No	Location (Km)	Before Treatment	After Treatment
1	69 RHS	1.74×10^{-5}	1.045×10^{-3}
2	80 LHS	1.22×10^{-5}	1.053×10^{-3}
3	90 LHS	1.02×10^{-5}	9.26×10^{-4}

Unconfined Compression Strength Value

After Finding the Optimum mix value of Iron Sludge and Virgin Soil, the Unconfined Compression test was carried out for natural soil and 20 percentage treated soil. The results are as shown below.

Sr. No.	Location (Km)	Before Treatment	After Treatment
1	69 RHS	0.8	1.52
2	80 LHS	0.825	1.53
3	90 LHS	0.765	1.50

5. COST ANALYSIS

The study incorporates the design of flexible pavement for the different CBR values of conventional material and treated materials as discussed in the previous sections along with assumed traffic conditions and the road configuration. Resources required for both the cases are figured out for each structural layer of the pavement and are presented in the comparative manner.

Quantifying the cost of stabilized soil is a very difficult issue to address. This is the result of several factors real figures can only be obtained when the full design of the construction makes use of all advantage of the treatment. The cost analysis is based on rate as per SOR and the treatment cost is considered referring DPR of study stretch at Dholera- Bhavnagar Highway.

Flexible Pavement Design

The structural capacity of flexible pavements is attained by combined action of the different layers of the pavement. The sub-grade layer is responsible for transferring the load from above layers to the ground. Flexible pavements are designed in such a way that the load transmitted to the sub-grade does not exceed its bearing capacity. Consequently, the thickness of layers would vary with CBR of soil and it would affect the amount of materials used in the pavement. Pavement design with treated soil and without treated soil carried out as per prevailing guidelines. There is replacement Sub Grade with treated soil.

Design procedure:

Natural Soil

Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of the natural soil pavement designs are added in the IRC: 37-2001 code. The pavement designs are given for subgrade CBR values ranging from 2% to 10% and design traffic ranging from 1 MSA to 150 MSA for an average annual pavement temperature of 35°C. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and sub-grade soil strength.

Pavement Thickness Determination

In order to design a pavement by CBR method, first the soaked CBR value of the soil subgrade is evaluated. Then the appropriate design curve is chosen by taking the design wheel load or by taking the anticipated traffic into consideration. Thus the total thickness of flexible pavement needed to cover the subgrade of the known CBR value is obtained.

In case there is a material superior than the soil subgrade, such that it may be used as sub- base course then the thickness of construction over this material could be obtained from the design chart knowing the CBR value of the sub-base. Thickness of the sub-base course is the total thickness minus the thickness over the sub-base, similarly thickness of all layers are calculated. CBR design chart recommended by IRC is Given Below in Figure.

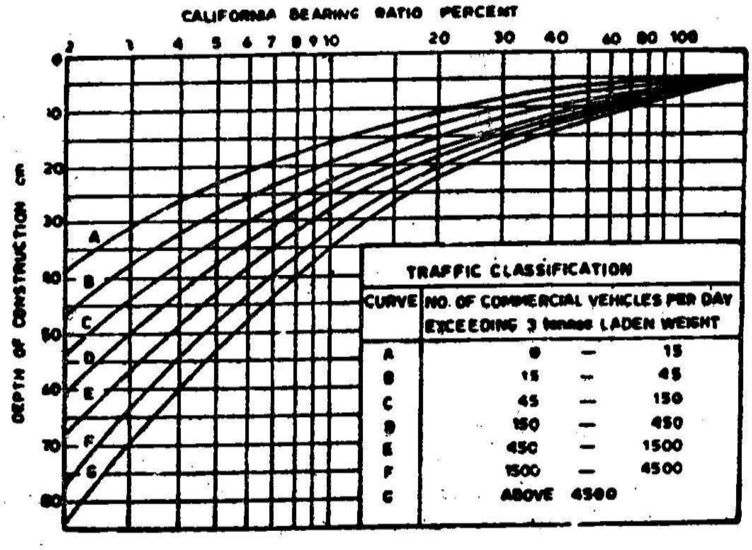


Fig. 7 CBR design Chart

Cost Calculation for Pavement with virgin Soil

The pavement design for Bagodara-Dhandhuka Highway having traffic between 10-150 msa. Cost calculation is carried out only for the provided crust. The cost calculation is shown in table no 6.1. The rates are as per study stretch work, quantities are worked out for 100 m length of road. The total cost for the above crust is worked out. The detail design calculations are shown here after

Inclusion in Benefit – With Improvement of C.B.R of Subgrade layer thickness

Pavement Composition of virgin Soil are Design CBR = 4.7 (Average of three), Traffic Considered = 75 msa (as per R & B Report), Design Period = 15 According to IRC 37: 2001, Total Thickness of pavement = 740 mm in Which G.S.B= 320 mm, W.M.M = 250 mm, D.B.M= 130 mm, B.C= 40 mm

Table 2: Cost Calculation for Existing Condition

Sr. No	Item Name	Quantity	Unit	Rate/M Ton	Cost
1	G.S.B.	384	M Ton	650	2,49,600
2	W.M.M.	300	M Ton	950	2,85,000
3	D.B.M.	224.25	M Ton	2200	4,93,350
4	B.C.	69	M Ton	3200	2,20,800
					1,248,750

Pavement Composition of Treated Soil

The pavement design for Bagodara - Dhandhuka Highway having traffic between 10-150 msa. Cost calculation is carried out for provided crust, material required for improve ment of properties, Equipment required for earth removal and vibration for proper mix, water required for fiber mix. The cost calculation is shown in table no 2. The rates are as per study stretch work, quantities are worked out for 100 m length of road. The total cost for the above crust is worked out. The detail design calculations are shown here after

Design CBR = 10.3 (Average of three), Traffic Considered = 75 msa, Design Periods = 15 years According to IRC 37: 2001, Total Thickness of pavement = 615 mm, G.S.B = 200 mm, W.M.M = 250 mm, D.B.M= 120 mm, B.C= 45 mm

Cost Calculation of Treated Soil

Table 3:Cost Calculation

Sr. No	Item Name	Quantity	Unit	Rate/ M Ton	Cost
1	G.S.B	240	M Ton	650	1,56,000
2	W.M.M	300	M Ton	950	2,85,000
3	D.B.M.	207	M Ton	2200	4,55,400
4	B.C.	77.625	M Ton	3200	2,48,400
					1,144,800

Total Benefit Analysis

Total Benefit governed by designing flexible pavement using treated soil (Improved C.B.R)= Total Cost with virgin soil – Total cost with improved soil i.e. **103,950** Rs/100 m

If we assume the cost of transportation of iron sludge from plant to site is 20,000 per 100 m road stretch. Then Net Benefit will be **103,950-20,000** = **83,950** Rs/100 m

So, 6.72 % saving can be achieved by

CONCLUSION:

As per above cited various relevant laboratory test were carried out with Proportion 4 (20% Iron Sludge). The study reveals the benefit from adding 20% Iron Sludge for Soil stabilization can save 83,950 Rs per 100 m of 7.5 meter wide stretch. Annual maintenance expenditure behind this road every year is very high because of pavement failure due to high swelling which is controlled 33 %.

Government resurface those pavement every year and at the end of monsoon it becomes very crucial. Soil stabilization can also reduce the maintenance cost. Industrial waste similar to iron sludge can be utilized for soil stabilization. Further research can be done to evaluate their feasibility. Feasibility of using iron Sludge for stabilization of other types of soils can also be evaluated.

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