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Effect of Flyash Stabilisation on Design of Flexible Road Pavement

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Abstract

The surface of the roadway should be stable and non-yielding, to allow heavy wheel load of road traffic. The road surface should also be even along the longitudinal profile to enable the fast vehicles to move safely and comfortably at the design speed. The earth road may not be able to fulfill any of the above requirements, especially during the varying conditions of traffic loads and the weather. At high moisture contents, the soil becomes weaker and soft and starts yielding under heavy wheel loads, thus increasing the tractive resistance. The unevenness and undulations of the surface along the longitudinal profile of the road causes vertical oscillations in the fast moving automobiles increasing the fuel consumption and the wear of the vehicle components resulting in considerable increases in the vehicle operation cost. Apart, form this uneven pavements surface cause discomfort and fatigue to the passengers of fast moving vehicles and cyclists. Therefore, in order to provide a stable and even surface for the traffic, the roadway is provided with a suitably designed and constructed pavements structure. Thus a pavements consisting of a few layers of pavements materials is constructed over a prepared soil sub-grade to serve as a carriageway.

In this paper an attempt has been made to find the routine properties and strength characteristics of soil of Muzaffarpur. The fiyash available as a byproduct of the thermal power station at Kanti, Muzaffarpur has been analysed. The effect of soil properties after mixing flyash with soil in different percentages has been studied. Flexible pavement thickness has been designed with different methods for natural soils as well as soil stabilised with different percentages of flyash. On the basis of analysis and design percentage saving in material of pavement (in the term of thickness) in the case of stabilised with flyash as compared to that of natural soil has been found out. Based on conclusion, it has been concluded that the flyash can be used for the economical pavement design and construction.

Keywords: Pavement, Flyash, Stabilisation, CBR Method, GroupIndex Method,Triaxial Method,Flexible Pavement.

Introduction

The surface of the roadway should be stable and non-yielding, to allow heavy wheel load of road traffic to move with least possible rolling resistance. The road surface should also be even along the longitudinal profile to enable the fast vehicles to move safely and comfortably at the design speed. The earth road may not be able to fulfill any of the above requirements, especially during the varying conditions of traffic loads and the weather. At high moisture contents, the soil becomes weaker and soft and starts yielding under heavy wheel loads, thus increasing the tractive resistance. The unevenness and undulations of the surface along the longitudinal profile of the road causes vertical oscillations in the fast moving automobiles increasing the fuel consumption and the wear of the vehicle components resulting in considerable increases in the vehicle operation cost. Apart, form this uneven pavements surface cause discomfort and fatigue to the passengers of fast moving vehicles and cyclists. Therefore, in order to provide a stable and even surface for the traffic, the roadway is provided with a suitably designed and constructed pavements structure. Thus a pavements consisting of a few layers of pavements materials is constructed over a prepared soil sub-grade to serve as a carriageway.

Aim and Objective of the Study

1. To find the routine properties and strength characteristics (Triaxial and CBR etc.) of soil of Muzaffarpur.

2. To analyse the fly ash available as a byproduct of the thermal power station at Kanti, Muzaffarpur.
3. To study the effect of soil properties after mixing fly ash with soil in different percentage.
4. Effect of mixing fly ash (in different percentages) on the pavement design in terms of thickness.
5. To find the percentage saving in material of pavement in the case of stablised soil with fly ash as compared to that of natural soil.
6. To explore the possibilities of using fly ash for grainful purposes.

ReviewofLiterature

Government of India has accorded highest priority to the large scale road improvement, development of road improvement and development of road infrastructure at a huge capital cost in the country through **National Highways Development Project (NHDP) and PradhanMantri Gram SadakYojna (PMGSY)**. Efficient and cost effective infrastructure system helps greatly in economic and industrial growth and in improving the quality of life of its people in a country. Advanced scientific methods, machineries and technical tools are now being deployed to facilitate the present standards. In view of extensive and enormous road construction activities taking place in the country which consume substantial natural resources, there is a strong need to incorporate technologies which would enable large scale use of alternate/new construction materials thereby reducing the quantities of materials, energy, labour and capital construction. Use of waste and marginal materials either on their own or in combination with other road construction materials have been suggested for reduction in pavement design thickness by new design techniques.

Efforts have been made at **Central Road Research Institute (CRRI),India** to explore the use of locally available materials as alternate materials for rural road construction. The locally available materials are cheaper, easily available and when suitably processed develop adequate strength. In spite of their advantages, local materials have not been utilized to their fullest extent.

CRRI India has been conducting studies to explore the possibilities of using local materials for rural road construction and its impact on construction cost. Large number of test tracks was constructed in different parts of the country depending upon the materials available in that area to study the behaviour of these materials under different conditions. Efforts were made to include different variables i.e. topography, climate, nature of sub grade soil, traffic, ground water table rainfall etc. while selecting the construction sites. Post construction performance of the test tracks was monitored for a period of 4 to 5 years.

Research & Development studies and successful field demonstration project have proved that waste materials like fly ash, iron and steel industry slags, municipal waste, rice husk ash. Marble slurry dust. Recycled concrete etc. can be used for construction of roads.

The specification suggested by the **Ministry of Road Transport and highways (MORT&H) and Indian roads congress (IRC)** has been recommended coarse graded GSB (Granular Sub-base) layer in case of rural roads.

In developing GSB mixes, the materials like natural sand. Moorum, gravel, crushed stone or combination of these are being. But in certain regions like konkan, belt of India. These materials are not available abundantly to meet the requirements of road construction activity. to satisfy the local needs, presently it has been carried out of following objective.

1. To alter the properties of the locally available materials by proper blending:
2. To proportion the blended soil with coarser materials to meet the requirements of GSB gradations.
3. To arrive at a design approach for developing GSB mixes.

According to design guide line of **American Association of State Highways Officials, Washington (AASHTO)** has been suggested to design pavement layer thickness by achieving the desired degree of compaction in the field, the fly ash being supplied to the job must be delivered to the site as close to its optimum moisture content as possible.

IS 10153-1982 has approved the process of flyash in many ways. Previously it was assumed that flyash was completely a waste material and can not be used except for filling low lying land. But in recent years, with the development of advance technologies, it has been indicated that flyash may be used as an alternative building and foundation material.

Laboratory and field studies conducted in India and Abroad have established that fly ash can also be adopted for stabilization of sub-base/base. Fly ash is a cohesion less material, and therefore, is non-plastic in nature while soil particles are generally cohesive. Mixing of soil with fly ash in suitable proportions improves the gradation and plasticity characteristics of the mix, thereby improving the strength.

Since Flyash produced in large quantities in thermal power plants are presently being dumped in slurry form in areas close to power plant. Therefore, many organizations such as **Central Building Resarch Institute (CBRI) Rookee, CBRI Dhanbad, Central Rural Research Institute, New Delhi, National council for Cement & Building Materials New Delhi etc**, are working on gainful utilization of flyash, its gainful utilization would provide a number of benefits such as environment pollution control, value added products etc.

Hypothesis and Methology

Soils samples will be collected from selected site of road length 1 km running from Majhauti to Katra Road, Muzaffarpur. Detailed investigations and laboratory tests (routine tests, CBR value etc.) will be carried out for collected natural soil samples as per Bureau of Indian Standard (BIS) Pavement design will be carried out on the basis of investigated soil properties and criteria laid down in Indian Road Congress (IRC).

Further, flyash will be procured from the Muzaffarpur Thermal Power Station, Kanti to ascertain its properties in laboratory and will be mixed in different percentage in collected samples. Properties of stabilized soil will be ascertained in laboratory. Effects of soil properties when mixed with different percentages of flyash will be studied on pavement design.

If encouraging results will be obtained in getting pavement thickness reduced by stabilizing soil with flyash in different percentage, great economy would be achieved by designing economical road pavement. In addition to economy, large consumption of flyash would be secured.

Muzaffarpur City

Muzaffarpur is one of the major towns of Bihar. It is situated near the historical Vaishali, one of the oldest republics of the world. The name of the city is after it's founder's name Muzaffarpur Khan who founded it in the 18^{th} Century. Muzaffarpur was the part of Lichhavi territory at the beginning of the 6th century B.C. and therefore, there are plenty of interesting historical sites around this area.

Muzaffarpur district is surrounded by East Champaran and Sitamarhi districts in the north, Vaishali in the south, Darbhanga and Samastipur in the east and Saran and Gopalganj district in west. It is located near BurhiGandakriver and spread over in the area of 3172 sq. kms.

Chronology of Investigation

Soils samples will be collected from selected site of road length 1 km running from Majhauti to Katra Road, Muzaffarpur. Detailed investigations and laboratory tests (routine tests, CBR value etc.) will be carried out for collected natural soil samples as per Bureau of Indian Standard (BIS) Pavement design will be carried out on the basis of investigated soil properties and criteria laid down in Indian Road Congress (IRC).

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Design Methods of Flexible Pavement

The flexible pavement design methods can be broadly classified into three distinct groups:

1. Empirical methods based on soil classification and other factors such as climate and moisture. They include the following:
   a. Group Index Method
   b. Federal aviation agency (U.S.A.) method.
2. Empirical methods based upon some arbitrary soil strength tests which have been correlated with pavement performance. These include :
   a. California Bearing Ratio (CBR) method.
   b. North Dakota Cone method.
   c. Plate bearing test method.
3. Theoretical and semi-theoretical methods. These include :
   a. Kansas triaxial method.
   b. Texas triaxial method.
   c. Burmister's method.

Composition of Fly Ash of Muzaffarpur Thermal Power Station, Kanti

The composition and properties of fly-ash been reviewed and is being tabulated below.

Physical Properties

Specific Gravity	2.33
Maximum Dry Density	1.45gm/cc
Optimum Moisture Content	28.20%
Co-eff. Of Permeability	$1.52x\ 10^{-3}$cm/s

Chemical Properties

Constituent	**Percentage**
Silica (SIO_2)	31.00%
Alumina (Al_2O^3)	21.82%
Ferric Oxide (Fe_2O_3)	20.50%
Calcium Oxide (CaO)	12.00%
Magnesia (MgO)	03.20%
Free Lime	03.50%
Unburnt Carbon	03.70%
Other minerals	04.28%

Table – 1
Details of Soil Properties and Strength Characteristics of Natural Soil Samples Collected From Majhouli to Katra Road

Sl No.	Sample No	I	II	III	IV	V
	Chainage in m	0	250	500	750	1000
1	**Specific gravity**	2.6	2.6	2.6	2.62	2.63
2	**Atterberg's Limit**					
	Liquid limit in %	34	33	34	33.7	38.1
	Plastic limit in %	22	23	24	24.3	26.1
	Plasticity index in %	12	9.2	9.5	9.4	12
3	**Compaction test**					
	(OMC)in %	18	19	18	16.8	18.9
	Dry density in gm/cm^3	1.7	1.7	1.7	1.62	1.63
4	**Triaxial test**					

	a)young's modulus in kg/cm^2	183	266	264	228	253
	b)cohesion in kg/m^2	0.3				
	c)angle of internal friction in degree	23^0				
5	**C.B.R test**					
	I.Unsoaked					
	a)at 2.5mm penetration in %	6.2	5.1	7.3	10.4	6.15
	b)at 5mm penetration in %	8.3	7	9.8	8.55	4.76
	II.Soaked					
	a)at 2.5mm penetration in %	4.4	4.1	5.4	8.76	4.6
	b)at 5mm penetration in %	6.1	5.4	7.6	6.8	3.63
6	**Passing 75 micron sieve in %**	35	32	34	31	37
7	**Particle size distribution in%**					
	Clay	6	3	3	2	6
	Silt	72	66	63	63	60
	Sand	22	31	34	35	34

Table - 2
Details of Soil Properties and Strength Characteristics of Natural Soil Samples Collected From Majhouli to Katra Road Mixed With 10% Flyash

Sl No.	Sample No	I	Ii	Iii	Iv	V
	Chainage in m	0	250	500	750	1000
1	**Specific gravity**	2.64	2.61	2.632	2.63	2.63
2	**Atterberg's Limit**					
	Liquid limit in %	27	26	26.2	26	34
	Plastic limit in %	20	18	17.7	18.5	24.5
	Plasticity index in %	7	8	8.5	7.5	9.5
3	**Compaction test**					
	(OMC)in %	15	17.25	16.2	14.25	17
	Dry density in gm/cm^3	1.71	1.72	1.68	1.64	1.65
4	**Triaxial test**					
	a)young's modulus in kg/cm^2	200	278	275	253	268
5	**C.B.R test**					
	I.Unsoaked					
	a)at 2.5mm penetration in %	8.78	10.55	10.41	14.25	9.27
	b)at 5mm penetration in %	11.5	8.15	12.52	11.2	7.5
	II.Soaked					
	a)at 2.5mm penetration in %	7.9	8.6	9.75	12.3	8.5
	b)at 5mm penetration in %	9.5	6.1	11.5	9.75	6.85
6	**Passing 75 micron sieve in %**	30	31	31	27	35
7	**Particle size distribution in%**					
	Clay	2	2	2	3	5
	Silt	64	62	60	60	60
	Sand	34	36	38	37	35

Table - 3
Details of Soil Properties and Strength Characteristics of Natural Soil Samples Collected From Majhouli to Katra Road Mixed With 20% Flyash

Sl No.	Sample No	I	Ii	Iii	Iv	V
	Chainage in m	0	250	500	750	1000
1	**Specific gravity**	2.654	2.624	2.64	2.644	2.644
2	**Atterberg's Limit**					
	Liquid limit in %	24	22.5	22.8	22	30
	Plastic limit in %	15.8	15.5	15.55	14.5	20.5
	Plasticity index in %	8.2	7	7.25	7.5	9.5
3	**Compaction test**					
	(OMC)in %	13.5	16	15.35	13.1	16
	Dry density in gm/cm^3	1.71	1.725	1.69	1.64	1.69
4	**Triaxial test**					
	a)young's modulus in kg/cm^2	224	287	283	263	276
5	**C.B.R test**					
	I.Unsoaked					
	a)at 2.5mm penetration in %	9.28	11.5	11.9	14.5	10.65
	b)at 5mm penetration in %	12.02	8	13.9	12.5	8.5
	II.Soaked					
	a)at 2.5mm penetration in %	7.4	10.5	9.8	13.9	8.8
	b)at 5mm penetration in %	9.8	7	12.5	10.41	6.8
6	**Passing 75 micron sieve in %**	24	25	24	23	29
7	**Particle size distribution in%**					
	Clay	2	1	2	2	4
	Silt	62	60	58	58	53
	Sand	36	39	40	40	43

Table – 4
Natural Soil collected from Majhouli – Katra Road

CHAINAGE in m	**Pavement thickness in cm**	**Pavement thickness in cm**	**Pavement thickness in cm**	**Pavement thickness in cm**
	CBR METHOD (UNSOAKED)	CBR Method (SOAKED)	GROUP INDEX METHOD	TRIAXIAL METHOD
0	40.5	48	31	39.62
250	44	52	30	23.7
500	36	43	30	25.9
750	34	37	30	29.5
1000	48	56	32	27.2
Average thickness in cm	40.5	47.2	30.6	29.18

Table - 5
Natural Soil Collected From Majhouli – Katra Road Mixed With 10% Flyash

CHAINAGE in m	**Pavement thickness in cm**	**Pavement thickness in cm**	**Pavement thickness in cm**	**Pavement thickness in cm**
	CBR METHOD (UNSOAKED)	CBR Method (SOAKED)	GROUP INDEX METHOD	TRIAXIAL METHOD
0	34	35	30	35.70
250	36	38	30	23.08
500	33	34	30	23.5
750	27	32	30	26.5
1000	38	38	30	24.4
Average thickness in cm	33.6	35.4	30	26.63

Table – 6
Natural Soil Collected From Majhouli – Katra Road Mixed With 20% Flyash

CHAINAGE in m	Pavement thickness in cm	Pavement thickness in cm	Pavement thickness in cm	Pavement thickness in cm
	CBR METHOD (UNSOAKED)	CBR Method (SOAKED)	GROUP INDEX METHOD	TRIAXIAL METHOD
0	34	35	30	30.83
250	32	33	30	21.87
500	30	32	30	27.35
750	27	31	30	24.88
1000	35	37	30.5	23.2
Average thickness in cm	31.6	33.6	30.1	24.63

Table -7
Comparision of Pavement Thickness Obtained by Different Methods With Mixing of Flyash In Different Percentages With Natural Soil

Sl no.	Soil composition and percentages savings	CBR method		GI method	Triaxial method
		UNSOAKED	SOAKED	In cm	In cm
1	**Natural soil**	40.5	47.2	30.6	29.18
2	**Soil with 10% flyash**	33.6	35.4	30	26.63
3	**Soil with 20% flyash**	31.6	33.6	30.1	24.63
4	**Percentage saving in pavement thickness w.r.t natural soil for 10 % mixing of flyash**	17.03	25	1.96	8.74
5	**Percentage saving in pavement thickness w.r.t natural soil for 20 % mixing of flyash**	21.96	28.81	1.63	15.59
6	**Percentage saving in pavement thickness w.r.t natural soil mixed with 10% flyash for natural soil mixed with 20% flyash**	4.93	3.81	0.33	6.85

Discussion

Discussion on results of Majhouli- Katra soils

The results of the various routine tests and strength characteristics of soils found for the selected road length of one km from Majhouli to Katra has been tabulated in table No.1. The percentage clay varies from 2% to 6 %. The percentage silt varies from 60 to 72 % and the percentage sand varies from 22% to 35 %.

The liquid limit varies from 32.6% to 38.1%, plastic limit varies from 22.1% to 26.1% and Plasticity Index varies from 9.2% to 12%. The optimum moisture content of the soil collected from different chainages of the road length indicated in the table varies between 16.8% to 19.1% while maximum dry density varies between 1.62 to 1.69 gm/cc. The CBR value for the same road length at the same chainages ranges between 5.1% to 10.35% for 2.5mm penetration and 4.76% to 9.81% for 5mm penetration in unsoaked condition whereas CBR value ranges from 4.1% to 8.76% for 2.5mm penetration and 3.63% to 7.55% for 5mm penetration in soaked condition (96 hours). These data indicate that soil of the selected road inherits good strength and is suitable for the road pavements.

Discussion on Results on Soil Fly Ash Mixture in Different Percentages

The fly ash has been mixed with soil sample collected from the different chainage (0m, 250m, 500m, 750m, 1000 m) of the road length of 1 km in Majhouli- Katra. The routine properties and strength characteristics test have been conducted and results have been presented in table 2 and 3.

The results show that the optimum moisture content of the soil fly ash mixture generally decreases while the dry density increases in the same condition.

By addition of fly ash in different percentage (10% and 20%) with natural soil, the percentage clay and silt size particles mostly decreases and the sand size particles of soil fly ash mixture generally increases. The average bulk density and maximum dry density increases with the increases of fly ash proportion in the soil. Addition of fly ash increases the CBR value both in soaked &unsoaked conditions. It is revealed from the table 1, 2 and 3. Where the test results of natural soil and fly ash mixtures in different percentages have been tabulated. There is only a trace of clay available in total length of the selected road length. Rate of gain of strength in quite considerable when fly ash is added to the soil at the rate of 10% by weight. Further addition of fly ash beyond the 10% and up to the 20% yields a slow rate of gain of strength.

Discussion on Design of Flexible Pavement

Although there are many methods of design of flexible pavement but only three methods, i.e. California bearing ratio, Group Index method &triaxial method have seen considered for determining the pavement thickness in the present study.

The results obtained by above mentioned methods for determining the pavement thickness, in the case of natural soil and mixed with different percentage of fly ash has been tabulated in Table-4, Table-5 and Table-6

In the case of natural soil the pavement thickness 29.18 cm obtained by the triaxial method is the least. The thickness 30.6 cm obtained by G.I. method gives slightly higher value. Thickness 40.5 cm obtained by CBR method in unsoaked condition gives higher value as compared to G.I. method whereas CBR method in soaked condition gives the highest value of pavement thickness i.e. 47.2 cm. The same trend is maintained in the case of soil mixed with the 10% and 20% fly ash. A comparative study regarding the percentage savings in pavement thickness has been made and details have been tabulated in Table-7. It is revealed from the table-7 the percentage savings in pavement thickness have been obtained using different methods of design of flexible pavements and found to vary from 1.96% to 25% in the case of soil stabilized with 10% fly ash. At the same time, the soil stabilized with 20% fly ash, varies from 1.63% to 28.81%, w.r.t. Natural soil. It has been studied from the table-7 the rate of percentage saving in pavement thickness is very rapid (i.e. from 1.96 to 25%) when the soil is mixed with 10% fly ash w.r.t natural soil but rate of percentage saving between 10% to 20% mixing of fly ash with natural soil is slow as compared to the percentage saving of thickness when soil is mixed with 10% fly ash.

Conclusion

It has been possible to draw the following conclusions for the natural soil of selected road length of one km from Majhoulia to Katra Road. Soil samples have been collected from the different chainages and mixed with the different percentages of fly ash. The conclusion has also been drawn for the saving in pavement thickness for the mixing of different percentages of fly ash using the flexible Pavement designs.

The soil of Majhoulia

Katra are alluvial in nature. Generally they contain sand and silt with only a trace of clay.

The fly ash when added to the soil in the proportion of 10% to 20% by weight has decreased the clay & silt content where as it has also increased the sand contents in soil. The maximum dry density has also increased on increasing fly ash proportion in the soil fly ash mixtures. It is therefore, concluded that the fly ash is the good stabilizing material.

The Soil of Majhoulia

Katra have a low plasticity and high CBR value. The fly ash which is by product of thermal power industry, contains silica, alumina, ferric oxide, magnesia, free lime and calcium oxide, By virtue of containing these materials, fly ash inherits pozzolanic and self hardening property.

Soil mixed with different percentage of fly ash (10% &20%) has a reasonable high value of CBR, both in soaked &unsoaked condition. Therefore it is concluded that fly ash may be a good sub-grade material for roads.

The effect of mixing fly ash in different percentage on the design of pavement in terms of thickness has been found 1.96% to 25% when the soil was mixed with 10% fly ash where as 1.63% to 28.81% when it was mixed with 20% fly ash.

Since the percentage reduction in pavement thickness has been found out by using flexible design methods, certainly there is saving in material of pavement, when it will be constructed.

Hence, it is therefore concluded that the fly ash can be used for the economical pavement design and construction.

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