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Rehabilitation And Upgradation Of An Existing Road Using Fly Ash, An Industrial By Product: A Case Study

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ABSTRACT

Fly ash a fine powder thrown out in large quantities from thermal power plants as a waste material in a by- product of combustion of pulverized coal. The disposal of fly ash poses a serious problem considering the air, water and soil problems. The solution to this problem lies in its bulk utilization of fly ash at dumping sites. This paper is summarized with brief details of the properties and design aspects of fly ash used in highway embankments. This paper investigates the improvements in the properties of expansive soils, as road subgrade stabilized with lime and fly ash in varying percentages. Laboratory tests were undertaken to study the swelling and strength characteristics of soils stabilized, fly ash and a combination of both. Soil and fly ash were added separately at ranges 0-50%, respectively, compaction, California Bearing Ratio (CBR), free swelling tests were performed on natural and treated soil samples. For the investigated admixture fly ash; comparing the results obtained of the natural and treated samples, the CBR and CS of fly ash treated samples increased significantly, coupled with the swelling reduction, depending on additive content. It

could be concluded that stabilization of subgrade soils by fly ash admixture is successful and more economical..

1. Introduction

Many gravel roads suffer from reduced bearing capacity mainly during soil frost thawing periods. The bearing capacity is to an outsized extent influenced by temperature and precipitation. The expected forthcoming climate change will lead to increased average annual many gravel roads suffer from reduced bearing capacity mainly during soil frost thawing periods. The bearing capacity is to an outsized extent influenced by temperature and precipitation. The expected forthcoming global climate change will cause increased average annual temperatures and rainfalls. Thus the soil frost periods will become shorter which can cause increased rutting and fewer bearing capacity in gravel roads. This will have implications for the forestry since the forest industry is to an outsized extent hooked in to accessible roads main a part of the year to urge the timber. To avoid the reduced bearing capacity, the gravel roads could also be stabilized. The Study section starts from Duburi at Design Km 388.000 and end at Chandikhole Town Design Km 427.400), with a total project length of 39.400 Km. As a major mining zone to transport the mining minerals from mines like Sukinda, Kalia Pani as well as finished products from factories for major industrial tycoon TATA Steel Ltd, JSPL, NilachalIspat, IMFA, Emami Cement, all they depend upon NH-53 as the major transportation mode by road. During those logistic operations, traffic density increased day by day over NH-53 from Duburi to Chandikhole, the merging point with NH-16. In order to facilitate that increased traffic with safe movement by all commuters, the existing NH-53 needs to widen and upgrade to 4 lanes as the existing road is compromises with intermediate/Two lane only. The present proposal, the existing 2 lane carriageway is now proposed to be widened to 4 lane carriageways by adding the part lane on either side with a toll plaza at design KM 400+000.

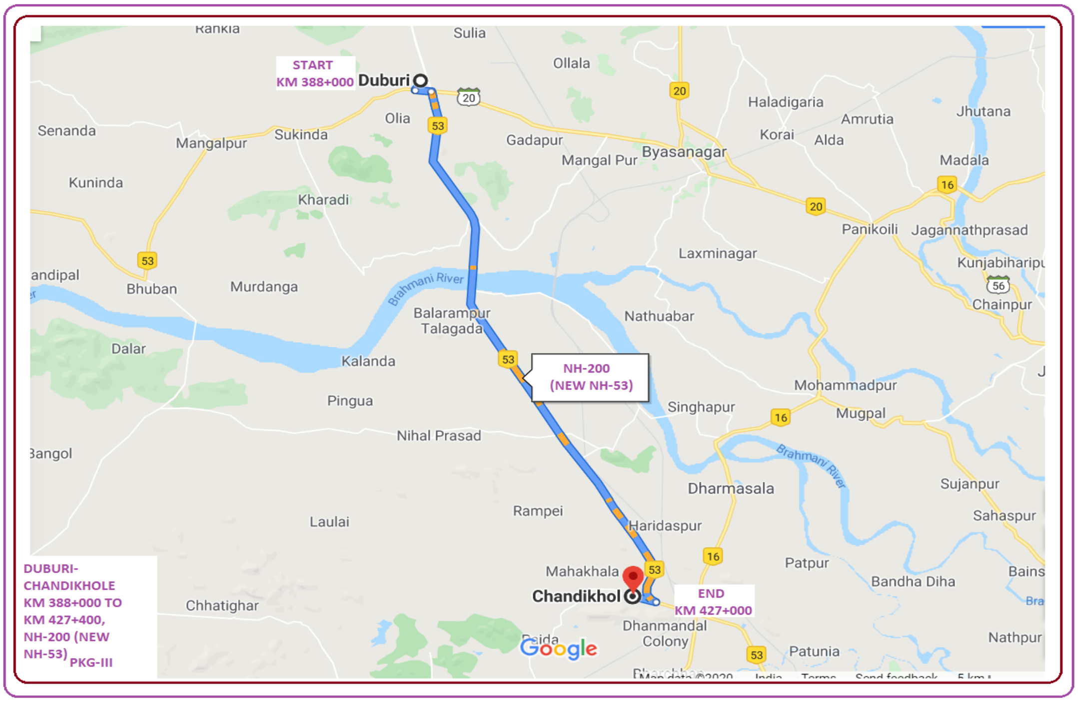

Figure 1: Location Map

2. Literature review

Soil stabilization is the process of creating or improving certain desired properties in a weak soil such as expansive clay so as to render it stable and useful for a specific purpose.[1] stated that the improvements in engineering properties caused by stabilization can include the following: increases in soil strength (shearing resistance), stiffness (resistance to deformation) and durability (wear resistance), reductions in swelling potential of wet clay soils and other desirable characteristics. There are many techniques for soil stabilization classified into two groups, mechanical or chemical stabilization. Mechanical or granular stabilization is accomplished by mixing or blending soils to obtain a material meeting the required specifications. Chemical stabilization involves mixing or injecting the soil with chemically active compounds like hydraulic cement , lime, fly ash, calcium or common salt or with bitumen materials. For successful soil stabilizer applications it is imperative to understand the mechanism of stabilization of additive, [2].When fly ash is added to an expansive soil reduces its plasticity, activity and swelling potential due to a cation exchange process (immediate reaction). The stable exchangeable cations provided by fly ash, such as Ca^{2+}, Al^{3+}, and Fe^{3+} promote flocculation of the clay particles. Furthermore, the time-dependent cementation process (pozzolanic reaction) results in cemented compounds characterized by high strength and low volume change, [3].He reported reductions in free swell index by 60% and 63%for two expansive soils A and B respectively with 15% class C ash . As observed by [3] that the percentage reduction in swelling potential of expansive soil composed of 85% Nabentoniteand 15% kaolinite was 52.6% and 58.3% by treating with 25% of fly ash-1 and fly ash-2 (both class-C),respectively. [4] Found a reduction of 65% in swelling potential by addition of 20% fly ash was nearly same as that by 8% lime. [4] Reported decrease in swelling pressure from 120 kPa to 90 kPa of expansive soil A and from 160 kPa to105 kPa of expansive soil B by treating with 12% fly ash. Both soils possessed high plasticity and were classified as CH. [5] found that the peak strength attained by fine fly ash mixture was 25% more when compared to coarse fly ash.

3. Need of study

- For best utilization of industrial waste material i.e. Fly ash as construction material for enhancing the engineering properties of soil reduces the demand of disposal and hence controls the source of pollution and protects the environment.
- Fly ash utilization solves landfill problems and to provide geomechanically stable material. Hence Fly ash is a economical alternative material in construction engineering.
- To resolve the landfill issues by utilization of Fly ash at low-lying area where either filling earth is not available or type of soil if of black cotton type.

4. Field investigation suyveys

Field investigations were carried out as a part of study with an objective to capture the requisite data for the design of rehabilitation and up gradation of existing pavements by overlay, widening and new construction;

4.1. Existing Pavement Crust Composition*:*

To assess the existing pavement crust composition test pits of size approx. 1m x 1m x 1m have been excavated alternatively on LHS and RHS at the interface of pavement edge and earthen shoulder interface extending through the pavement layers down to Subgrade level.

The existing crust was observed during the test pits and has been classified as follows:

- BituminousSurface
- Granular base/Sub-basecourse

The summary of pavement crust details are given in Table 4.1.

Table 4.1: *Existing Pavement Crust*

Layer	**Existing pavement Crust**		
	Average	**Minimum**	**Maximum**
Bituminous Layer	98	50	155
Granular Base/Sub base	398	270	550
Total Crust	**496**	**320**	**705**

4.2. Existing Subgrade Investigation:

Subgrade investigation test were conducted for evaluation of existing Subgrade. Soil samples from the existing Subgrade top were collected from locations along the project stretch. 10 numbers of samples were taken for analysis. The soil samples were tested for various parameters like Atterberg's limits, CBR etc. The summary of test results conducted on existing Subgrade soil samples are summarized in Table 4.2.

Table 4.2: *Summary of Existing Subgrade Test Results*

S. No.	**Location**	**Field Moisture Content (%)**	**Sieve Analysis (% Passing by weight)**			**Atterberg's Limit IS: 2720 Part:5**			**Free Swell Index (%)**	**MDD (gm/cc)**	**OMC (%)**	**Avg. Un- Soaked CBR at 4 days in 3 energy level (%)**	**Avg. Soaked CBR at 4 days in 3 energylevel (%)**	**Soil Classification**
			(20 mm to 4.75	**(4.75 mm to**	**(< 0.075 mm)**	**LL (%)**	**PL (%)**	**PI (%)**						
1	389+580 (LHS)	5.85	7.83	50.20	41.97	29	20	9	13.0	2.08	10.50	25.30	16.20	SC
2	390+420 (RHS)	5.99	10.97	59.38	29.65	19	-	NP	Nil	2.1	8.9	27.0	18.0	SM
3	392+840 (LHS)	4.51	33.51	27.44	39.05	26	18	8	10	2.12	9.10	30.20	20.80	GC
4	396+880 (RHS)	6.18	14.51	43.05	42.44	30	21	9	10.0	2.06	10.80	22.60	15.30	SC
5	403+100 (LHS)	5.34	32.18	31.04	36.78	26	17	9	10.0	2.10	9.60	22.40	19.10	GC
6	407+670 (RHS)	7.94	12.95	38.57	48.48	30	20	10	13.0	2.05	10.10	27.20	15.20	SC
7	412+600 (LHS)	6.40	17.27	44.41	38.33	28	-	NP	Nil	2.09	9.20	33.20	17.30	SM
8	418+100 (RHS)	7.09	16.97	41.06	41.96	29	19	10	10.0	2.07	9.90	28.20	15.90	SC
9	422+600 (LHS)	6.22	32.59	29.69	37.72	27	18	9	10.0	2.13	8.30	39.10	20.10	GC
10	425+760 (RHS)	6.45	31.07	30.70	38.23	26	18	8	10.0	2.11	9.50	36.15	19.70	GC

4.3. Pavement Evaluation by Falling Weight Deflectometer:

A falling mass in the range of 200 kg is dropped from a height of fall in the range of 100 to 600 mm to produce load pulses of desired peak load of 40 kN (+/- 4 kN) and duration of 20- 30ms. The target peak load of 40 kN (+/- 4 kN) applied on bituminous pavements corresponds to the load on dual wheel set of a 80 kN standard axle load and duration of 20-30 ms simulates traffic moving at a speed of 60Kmph. The corresponding peak vertical surface deflections at different radial locations are measured and recorded. The target peak load can be decreased suitably if the peak maximum (central) deflection measured with 40 kN load exceeds the measuring capacity of the deflection transducer. If the applied peak load differs from 40 kN within the above-mentioned range, the measured deflections have to be normalized linearly during the analysis to correspond to the standard target load of 40 kN. Sufficient number of deflection transducers shall be used to adequately capture the shape of deflection bowl. Six to nine velocity transducers (geophones) are generally adequate for measuring surface deflections of flexiblepavements. For the present work, the defined mass has been dropped form a variable height to produce the target load and deflections have been measured from 7 deflection transducers placed at 0, 200,300, 450, 600, 900, and 1200. Summary of FWD test are given in Table 4.3.

Table 4.3: *Summary of Results of FWD Survey*

Sl. No.	Homogenous Sections		Thickness, mm		Moduli, Mpa			Strains	
	From	To	Existing BT	Existing Granular	BT	Granular	Subgrade	Tensile	Vertical
DUBURI-CHANDIKHOLE									
1	390+000	393+500	100	530	1977	198	96	0.0003187	-0.0002776
2	393+500	396+250	100	530	1912	198	96	0.0003240	-0.0002786
3	396+250	399+750	100	200	1888	159	96	0.0003779	-0.0006999
4	399+750	411+250	75	200	1886	179	93	0.0004299	-0.0008511
5	411+250	423+750	70	345	1837	187	87	0.0004231	-0.0005832
6	423+750	427+000	70	390	1807	156	89	0.0004704	-0.0005309

4.4. Axle Load Survey:

Traffic load is dominant function on pavement design. Axle load survey is carried out to determine the loading pattern of the heavy vehicles using the road. VDF calculation from axle load survey is attached in Table 4.4.

Table 4.4: *Summary of Results of Axle Load Surve*

S.No.	Vehicle Type	Axle Configuration	Wheel Weight (Tonnes)							VDF-Front Axles	VDF-Rear Axle	Total VDF
			Axle-1	Axle-2	Axle-3	Axle-4	Axle-5	Axle-6	Axle-7			
1	4 Axle	1.2.22	2120	1860	1485	1500				0.168	0.068	0.236
2	3 Axle	1.22	1975	1985	1925					0.126	0.072	0.198
3	3 Axle	1.22	2320	5450	5500					0.240	4.440	4.681
4	2 Axle	1.2	3116	4264						0.783	1.196	1.979
5	3 Axle	1.22	1945	1715	1520					0.119	0.034	0.153
6	2 Axle	1.2	2846	4516						0.545	1.505	2.049
7	4 Axle	1.2.22	2690	5100	5690	5900				0.435	8.020	8.455
8	2 Axle	1.2	3066	4164						0.734	1.088	1.821
9	2 Axle	1.2	2923	3641						0.606	0.636	1.242

10	3 Axle	1.22	3548	8246	8135					1.315	22.239	23.554
11	3 Axle	1.22	2490	5310	5505					0.319	4.225	4.544
12	LCV Goods	1.2	2015	2995						0.137	0.291	0.428
13	2 Axle	1.2	3423	4964						1.140	2.197	3.336
14	2 Axle	1.2	3160	4250						0.828	1.180	2.008
15	5 Axle	1.2.222	2648	2961	4963	5134	5202			0.213	0.065	0.278
16	2 Axle	1.2	2950	5031						0.629	2.318	2.946
17	3 Axle	1.22	1850	1689	1602					0.097	0.036	0.133
18	LCV Goods	1.2	2416	4560						0.283	1.564	1.847
19	4 Axle	1.2.22	2225	2110	1950	1850				0.203	0.136	0.340
20	2 Axle	1.2	2510	4689						0.329	1.749	2.078
21	3 Axle	1.22	2564	3256	3425					0.359	0.615	0.974
22	2 Axle	1.2	2467	4160						0.307	1.083	1.391
23	2 Axle	1.2	2946	5713						0.625	3.854	4.479
24	2 Axle	1.2	2476	3466						0.312	0.522	0.834
25	4 Axle	1.2.22	2010	2550	2690	2725				0.135	0.419	0.554
26	2 Axle	1.2	2520	5234						0.335	2.715	3.050
27	4 Axle	1.2.22	2646	2550	2416	2640				0.407	0.355	0.762
28	3 Axle	1.22	2150	5320	5610					0.177	4.408	4.585
29	2 Axle	1.2	2820	4634						0.525	1.668	2.193
30	2 Axle	1.2	2620	3648						0.391	0.641	1.032
31	3 Axle	1.22	2290	5050	4955					0.228	3.095	3.323
32	2 Axle	1.2	2850	4369						0.548	1.318	1.866
33	LCV Goods	1.2	2095	3650						0.160	0.642	0.802
34	3 Axle	1.22	2578	5367	5589					0.367	4.450	4.817
35	2 Axle	1.2	3600	5676						1.394	3.755	5.149
36	5 Axle	1.2.222	2946	3035	5289	5237	5067			0.158	0.113	0.272
37	BUS	1.2	2540	3920						0.346	0.854	1.200
38	4 Axle	1.2.22	3012	2944	3152	3424				0.683	0.849	1.533
39	2 Axle	1.2	4034	7971						2.198	14.605	16.803
40	2 Axle	1.2	3416	7603						1.130	12.089	13.219
41	BUS	1.2	2490	3920						0.319	0.854	1.173
42	2 Axle	1.2	2985	6532						0.659	6.586	7.245
43	2 Axle	1.2	2897	6523						0.585	6.550	7.134
44	4 Axle	1.2.22	2050	2190	5415	5690				0.147	4.780	4.927
45	2 Axle	1.2	4154	9282						2.472	20.555	23.027
46	3 Axle	1.22	3089	7164	6982					0.756	12.368	13.123
47	4 Axle	1.2.22	2950	2620	4210	5090				0.629	2.481	3.110
48	2 Axle	1.2	3260	6146						0.938	5.162	6.099
49	2 Axle	1.2	3816	5410						1.760	3.099	4.859
50	2 Axle	1.2	3690	7640						1.539	12.326	13.865
51	BUS	1.2	2245	2648						0.211	0.178	0.389
52	2 Axle	1.2	2840	4490						0.540	1.470	2.010
53	3 Axle	1.22	3658	7859	7994					1.486	19.507	20.994
54	2 Axle	1.2	2650	4090						0.409	1.012	1.422
55	3 Axle	1.22	2545	5379	5246					0.348	3.936	4.284
56	2 Axle	1.2	2740	6095						0.468	4.993	5.461
57	3 Axle	1.22	2740	5849	5674					0.468	5.445	5.913

58	3 Axle	1.22	2920	8160	8616					0.603	24.463	25.066
59	2 Axle	1.2	3460	4694						1.190	1.756	2.946
60	5 Axle	1.2.222	2250	2135	1950	2040	1590			0.213	0.132	0.345
61	2 Axle	1.2	3546	8166						1.312	16.087	17.399
62	2 Axle	1.2	4026	7613						2.181	12.152	14.333
63	2 Axle	1.2	2679	4251						0.428	1.181	1.609
64	2 Axle	1.2	2486	5243						0.317	2.734	3.051
65	2 Axle	1.2	3012	6816						0.683	7.808	8.491
66	2 Axle	1.2	2580	4075						0.368	0.998	1.365
67	2 Axle	1.2	3616	7522						1.419	11.582	13.001
68	3 Axle	1.22	3850	8724	9024					1.824	30.644	32.468

4.5 Traffic Volume Count Survey:

Table 4.5: *Summary of Results of Traffic Projection*

year	**Car**	**3 wheeler**	**2 wheeler**	**Mini bus**	**bus**	**LCV**	**2 Axle**	**3 axle**	**Multi Axle**	**Tractor**	**Tractor and tractor with Trailor**	**Cycle**	**Cycle Rickshaw**	**Animal drawn**	**Total AADT**
2018	457	130	1150	39	30	440	3321	937	93	7	11	288	63	0	**6966**
2019	480	137	1208	41	32	462	3487	984	98	7	12	302	66	0	**7314**
2020	504	144	1268	43	33	485	3661	1033	103	8	12	317	69	0	**7680**
2021	529	151	1331	45	36	509	3844	1085	108	8	13	333	73	0	**8065**
2022	555	158	1398	48	36	537	4036	1139	114	8	14	350	76	0	**8470**
2023	583	166	1468	50	38	564	4238	1196	119	9	14	367	80	0	**8894**
2024	612	175	1541	53	40	592	4450	1256	125	9	15	385	84	0	**9338**
2025	643	183	1618	55	42	622	4673	1318	131	10	16	405	88	0	**9805**
2026	675	192	1699	58	44	653	4906	1384	138	10	17	425	93	0	**10296**
2027	709	202	1784	61	47	686	5152	1454	145	11	18	446	97	0	**10810**
2028	744	212	1873	64	49	720	5409	1526	152	11	18	468	102	0	**11351**
2029	782	223	1967	67	51	756	5680	1603	160	12	19	492	107	0	**11919**
2030	821	234	2065	71	54	794	5964	1683	168	12	20	516	113	0	**12514**
2031	862	246	2168	74	57	834	6262	1767	176	13	21	542	118	0	**13140**
2032	905	258	2277	78	59	875	6575	1855	185	14	22	569	124	0	**13797**
2033	950	271	2391	82	62	919	6904	1948	194	14	23	598	130	0	**14487**
2034	998	284	2510	86	65	965	7249	2045	204	15	25	628	137	0	**15211**

5. Experimental studies

Experimental Studies were carried out as a part of study with an objective to capture the requisite data for the design of rehabilitation and up gradation of existing pavements by overlay, widening and new construction;

1. Geotechnical Properties of Fly ash
2. Free Swelling Index
3. Compaction Test
4. CBR Test

5.1 Geotechnical Properties Of Fly ash:

S. No.	Parameter	Result/Value
1	Specific Gravity	2.4
2	Plasticity	Non-Plastic
3	Maximum Dry Density (gm/cc)	1.2
4	Optimum Moisture Content (%)	35
5	Cohesion (kN/m^2)	Negligible
6	Angle of Internal Friction (Φ)	34^0
7	Particle size Distribution (%)	
	Clay size fraction	0
	Silt size fraction	79

Table 5.1: *Summary of Results of Geotechnical Properties of Fly ash*

5.2 Free Swelling Index:

The variation of FSI with percentages of Fly ash of 6 trial mixes is presented in Figure 5.1. From this figure, it can be seen that as thepercentage ofFly ashincreases from 0 to 50%, there is significant reduction in FSI.The reduction in FSI is noticed higher up to about 50% of Fly ash and thereafter almost little decrement is noticed with addition of Fly ash.

Table 5.2: *Summary of Results of FSI*

Trial Mix	Soil	Fly ash	FSI%
T1	100	0	66.6
T2	90	10	50
T3	80	20	33.3
T4	70	30	20.6
T5	60	40	9.1
T6	50	50	4.2

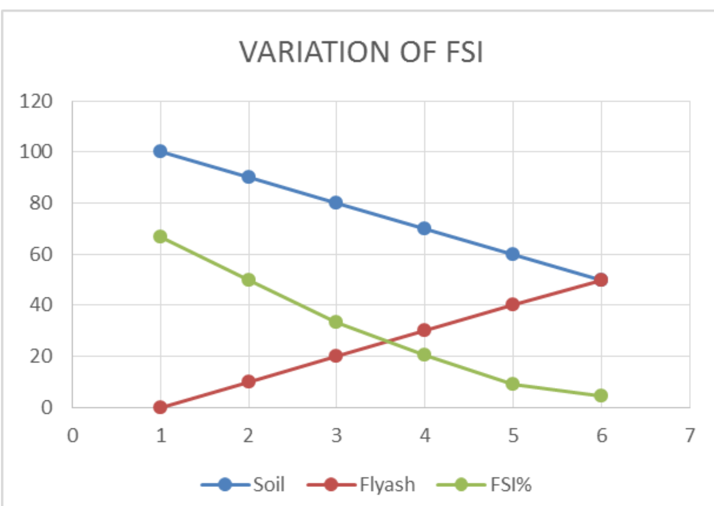

Figure5.1: *Graphical Representation of FSI*

5.3 Compaction Test:

The variation of OMC with percentages of Fly ash of the three soils is presented in Figure 5.2. From this figure, it can be seen that as the percentage of Fly ash increases from 0 to 30%, there is significant reduction in OMC. The OMC value reduces up to 12 i.e. with addition of 30 percentage of fly ash, then after 30% it increases i.e. around 15.2 percent at 50 % replacement of fly ash.

Table 5.3: *Summary of Results of OMC*

Trial Mix	Soil	Flyash	0MC (%)
T1	100	0	16
T2	90	10	10.7
T3	80	20	12.7
T4	70	30	12
T5	60	40	14.5
T6	50	50	15.2

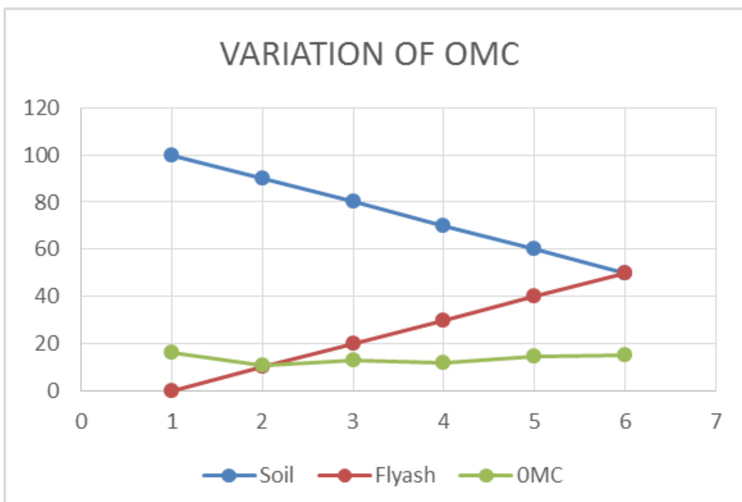

***Figure5.2**: Graphical Representation Of OMC*

The variation of MDD with percentages of Fly ash of the three soils is presented in Figure 5.3. From this figure, it can be seen that as the percentage of Fly ash increases beyond 30%, there is significant reduction in MDD. The reduction in OMC is noticed higher up to about 25% of fly ash and thereafter almost little decrement is noticed with addition of Fly ash.

Table 5.4: *Summary of Results of MDD*

Trial Mix	Soil	Fly ash	MDD (kg per cum)
T1	100	0	1.68
T2	90	10	1.76
T3	80	20	1.74
T4	70	30	1.63
T5	60	40	1.73
T6	50	50	1.62

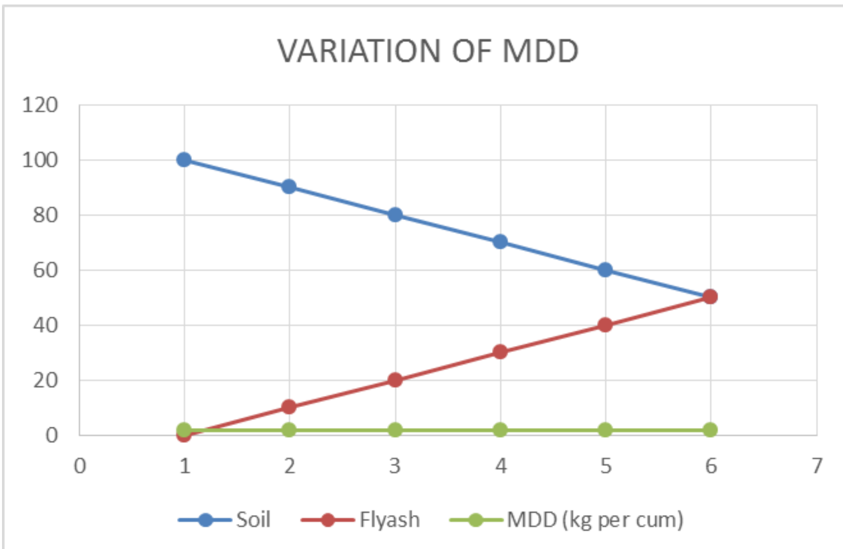

Figure 5.3: *Graphical Representation Of MDD*

5.4 CBR Test:

The variation of CBR with various percentages of Fly ash is presented in Figure 5.4. From this figure, it can be seen that as the percentage of Fly ash increases from 0 to 30%, there is significant reduction in CBR.

Table 5.5: *Summary of Results of CBR*

Trial Mix	Soil	Flyash	CBR (%)
T1	100	0	2.06
T2	90	10	2.47
T3	80	20	2.47
T4	70	30	2.68
T5	60	40	2.67
T6	50	50	2.47

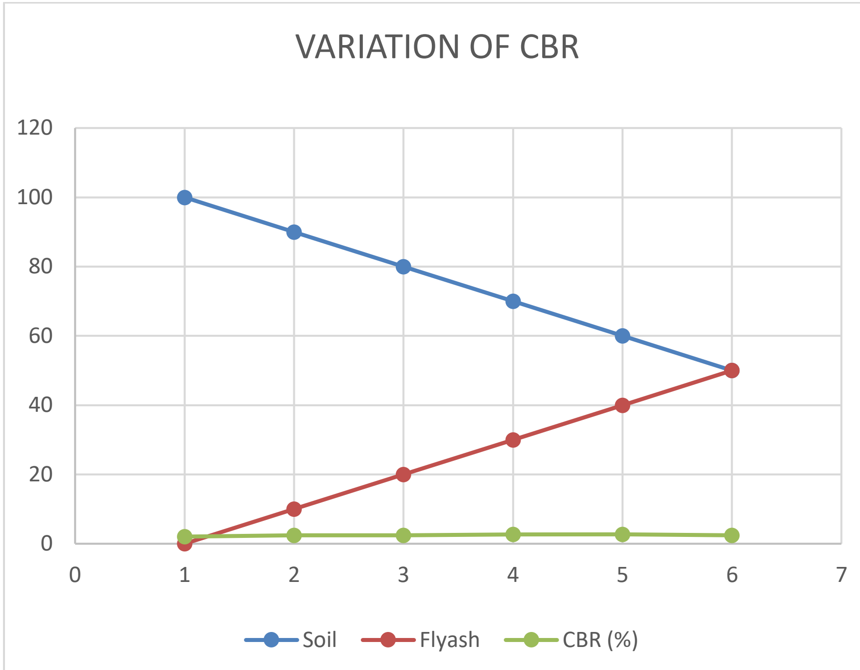

***Figure5.4**: Graphical Representation of CBR*

6. Conclusion

Fly ash has considerable geotechnical, and physical propertiesdue to which fly ash can be substitute to soil and avoiding depletion of natural geo materials.Problems like disposal of industrial wastes and environmental pollution can be sorted out partly, if fly ash is used as an embankment material, this paper has been attempted to promote the use of fly ash as an embankment material in highway engineering. Addition of fly ash reduces the swelling behaviour of soil. So it is proved that fly ash controls the swell shrink property of soil.

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