Changing the physical, chemical properties of alkaline soil stabilised with industrial waste material tile dust

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Abstract: The main objective of this research work is the improvement of pavements' load-bearing capacity that are constructed on Kurukshetra alkaline soils by tile dust. Soil samples from Pehowa-Kurukshetra road are collected and put under testing for enhancing their properties by tile dust at different dosages ranging from 2–12%. Finally, the test result has reviewed that the maximum dry density gets minimised and the optimum moisture content gets increased with the supplement of admixture. Tests including California bearing ratio test (CBR) and unconfined compression tests (UCS) are done for evaluating the strength properties of alkaline soil. Chemical test due to the reaction in the submerged condition is performed in CSSRI lab in Karnal Haryana. At last, the test results specify that the tile dust significantly enhances the performance of soil. Thereby, the improved soil is utilised as a good sub-base in flexible pavements in construction work.

Keywords: Kurukshetra; tile dust; alkaline soils; admixture; California bearing ratio test; CBR; unconfined compression tests; UCS; optimum moisture; CSSRI lab; chemical test; construction work.

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1 Introduction

In fact, the alkaline soils (Bian et al., 2011; Luo et al., 2010; Zhang et al., 2003, 2009) are related to various geotechnical problems because of the being of digenetic salts under various shapes, sizes and compositions. Therefore, alkaline soil is concerned as an inferior construction material. Due to these respective characteristics, certain pavements that placed on alkaline flats have shown different deterioration types concerning cracking, ravelling, rutting and nowadays built roads. The soils' susceptibility to loss of strength and collapse upon wetting often paves the way in risky and hazardous construction. More importantly, alkaline soils (Rajakumar et al., 2014; Gupta et al., 2011; Wang et al., 2009, 2010; Song and Wang, 2011; Morerira et al., 2019; Barbosa et al., 2019; Barbari et al., 2014) are accepted with respect to shear strength as well as rigidity in natural conditions; however, they radically change in the presence of water, extreme deformations and triggering significant localised settlements.

Already, numerous studies were made about the geotechnical behaviour of alkaline soils in the projects of civil engineering in various countries (Goyal et al., 2007; Basha et al., 2005; Cordeiro et al., 2009). Moreover, various models were utilised for enhancing the alkaline soil's inferior properties that include geotextile reinforcement, vibratory compaction, soil replacement, deep soil densification as well as stabilisation with tile dust and cement (Dhawan et al., 1994; Choobbasti et al., 2010; Anupam et al., 2013). Edeh et al. (2014), Kumar et al. (2014) and Sabat (2012) have examined the influence factors on solidified's compressive strength in shore alkaline soil with the ratio of tile dust (1: K), tile dust, tile dust-ash quantity, age, compression degree and content of salt by performing certain unconfined compressive strength test. Along with this, they have also reported that since there have special engineering properties, there needs to consider some of the more influencing factors while compared to the ordinary soil to attain the perfect impact of solidifying.

In India, almost 15% of the area is covered by alkaline soils (Figure 1), which causes various damages in projects of civil engineering. Till now, more research works are done for studying the impacts of alkaline soils in the geology field and agriculture (Puri, 2012). Nevertheless, only a few studies took place on analysing the alkaline soil's stabilisation and geotechnical behaviour in India (Kumar et al., 2014; Sabat, 2012; Jain and Puri, 2013). This paper presents the Kurukshetra alkaline soil's geotechnical behaviour and the most suitable improvement model for enhancing the load capacity of pavements. Further, this work gives the laboratory studies of enhancement of characteristics (strength) of loose subgrade alkaline soil with Pehowa-Kurukshetra road by tile dust. California bearing ratio test (CBR) and the unconfined compression tests (UCS) are used to assess the stabilised soil mixtures' load-bearing capacity.

Figure 1 Coverage of alkaline soil in Haryana

2 Proposed work

2.1 Materials

2.1.1 Alkaline soil

The used alkaline soil is gathered from Pehowa Kurukshetra. Further, the used soil of medium compressibility is (A-7-6) soil. Further, the index properties including plastic limit, liquid limit, plasticity index as well as some other vital soil properties according to the AASHTO as well as the US Soil Classification Systems is given in Table 1.

Table 1 Chemical and physical properties of soil and tile dust

	Physical properties		
S. no.	*Property*	*Soil*	*TD*
1	Specific gravity	2.63	2.55
2	(MDD), g/cc	1.96	-
3	(OMC), (%)	12.5	-
4	Liquid limit (%)	37	-
5	Plastic limit (%)	23	NP
6	Is classification	CL	SM
	Chemical properties		
S. no.	*Constituent %*	*Soil*	*TD*
1	Loss on ignition LOI	5.20	0.43
2	Silica SiO_2	69.16	64.01
3	Iron Fe_2O_3	4.13	2.09
4	Aluminium Al_2O_3	15.62	18.34
5	Calcium CaO	2.23	8.82
6	Magnesium MgO	1.04	4.43
7	Sodium Na_2O	0.21	0.21
8	Potassium K_2O	1.05	0.89
9	Sulphur trioxide SO_3	0.20	0.15

2.1.2 Tile dust

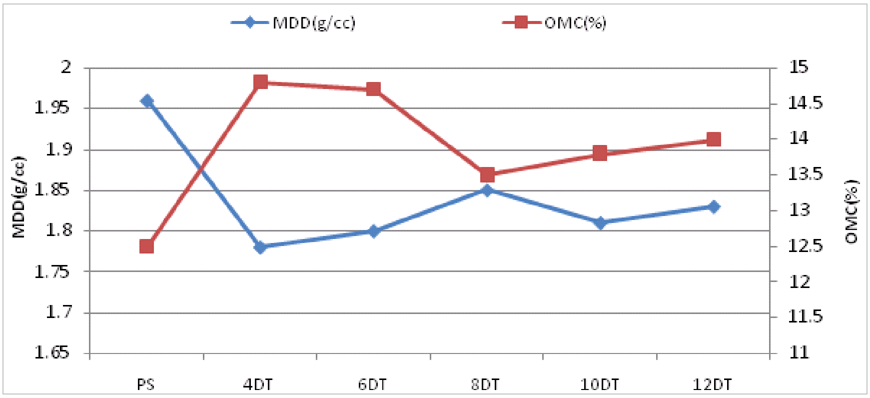
Tile waste used in the study was collected from the campus on NIT Kurukshetra construction site. Tile waste is crushed in the geotechnical laboratory as a fine grain powder. The engineering and chemical properties of tile dust depend on the kind of tile. Table 1 illustrates the properties of soil and tile dust.

3 Experimental results

3.1 Laboratory examination and interpretation of outcomes standard Proctor test

The soils' geotechnical assets are purely based on to the density and moisture, where the soil gets compacted. In general, a high level of soil compaction improves the soil's geotechnical parameters. The major objective of the Proctor test (moisture-density test) is to define the maximum dry densities (MDD) and optimum moisture contents (OMC) of both treated stabilised soil-mixtures as well as untreated compacted. To attain the respective parameters, we have employed the standard compaction test for the stated mixture proportions according to IS: 2720 (Part 8). Further, the outcome of OMC and MDD for soil stabilised with tile dust is as shown in Figure 2.

Figure 2 Outcomes of OMC and MDD for soil stabilised with tile dust (see online version for colours)

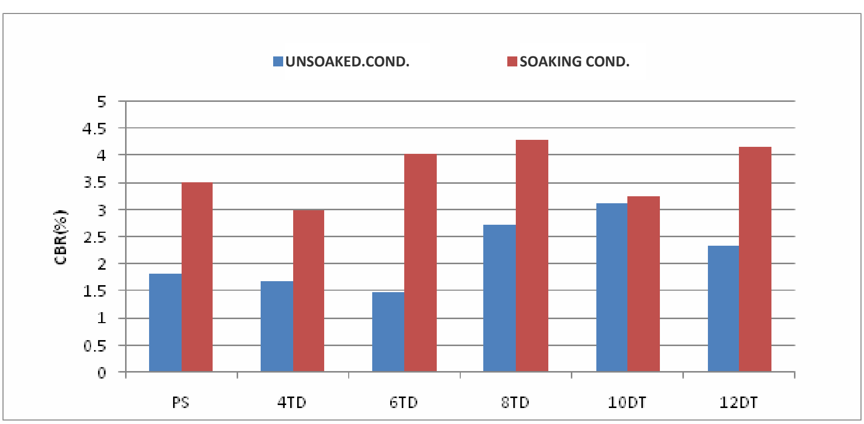


3.2 CBR testing

In fact, it is very important to develop a simple penetration test for evaluating the road subgrades strength. The subgrade resistance is also determined. Moreover, simply, 'How stronger the ground that we are going to develop the road'. Increasing of CBR reading reveals the stronger subgrade and minimal thickness needed for designing and constructing the road pavement, and which gives the substantial cost saving. On the contrary, lower CBR reading specifies that the subgrade is really weak and we should develop a proper thicker pavement of road for spreading the wheel load on the larger area that the weak subgrade material is not distorted,

The soil samples were admixed with 4% tile dust to 12%, which is cured for 1 day. Tests have been conducted with these samples after the process of soaking in water for 4 days, according to IS 2720 (Part 16). The outcomes of the average CBR values of every sample for soil-TD are as shown in Figure 3.

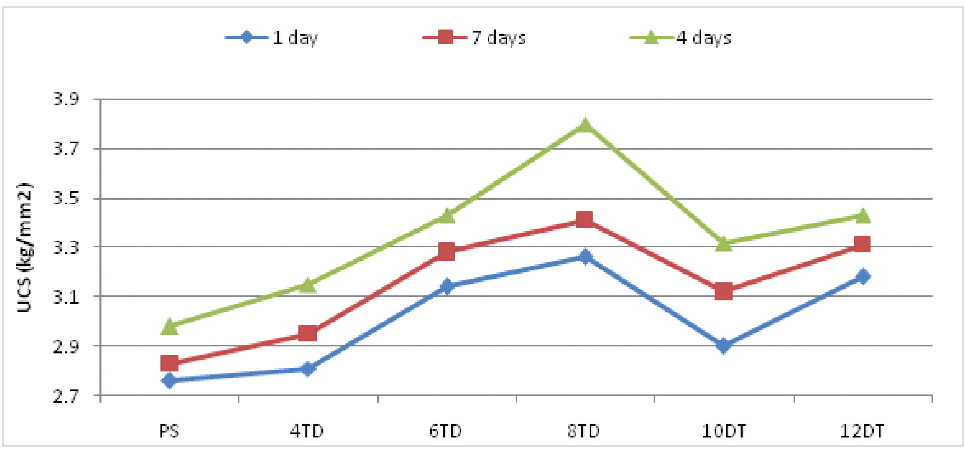
Figure 3 Outcomes of average CBR values of each sample for soil-TD (see online version for colours)



3.3 UCS testing

In this, the UCS test is done to rapidly attain the compressive strength's measure for soils, which acquires adequate cohesion for permitting testing in the unconfined state. Then, they have completed the oven-dried mixtures. With the use of split-cylindrical mould of size 38 mm (internal diameter) by 76 mm (height of the mould), they attain corresponding OMC. The trimming of compacted mixed samples is happened to the height of 76 mm and this is done after the elimination of mould collar. Subsequently, the elimination of compacted samples that were trimmed is done from the divided UCS mould and has sealed using polyethylene bags (double wrapping). This is kept under somewhere (humidity room) for allowing uniform moisture distribution, which is cured at 25–2°C temperature for one day. Some other sites are kept in uniform moisture distribution for four to seven days, and the final sets are given immediately to UCS test after extruding. This is for assessing the strength under various curing conditions. The test result is illustrated in Figure 4.

Figure 4 Test result of UCS (see online version for colours)



4 XRD characterisation

4.1 Alkaline soil

The experiment has also used the X-ray diffraction (XRD) for characterising the alkaline soil along with the reaction products having 4 % calcium sulphate. There obtain the XRD patterns by Siemens D5000 powder X-ray diffraction machine. Further, the preparation of XRD Specimens was done from air-dried soils under both cases: without and with contamination. The placement of a soil sample (c. 2 g) is there, and it was about 3 mm deep. The analysing of all samples is done by parallel beam optics along with radiation of CuKa at 40 kV and 30 mA. Finally, the samples were subjected to scan for that is under the range 0 to 70 at a step size of 0.02 and a 2 s count time per step.

4.2 Measurement conditions

Table 2 shows the respective measurement condition of alkaline soil.

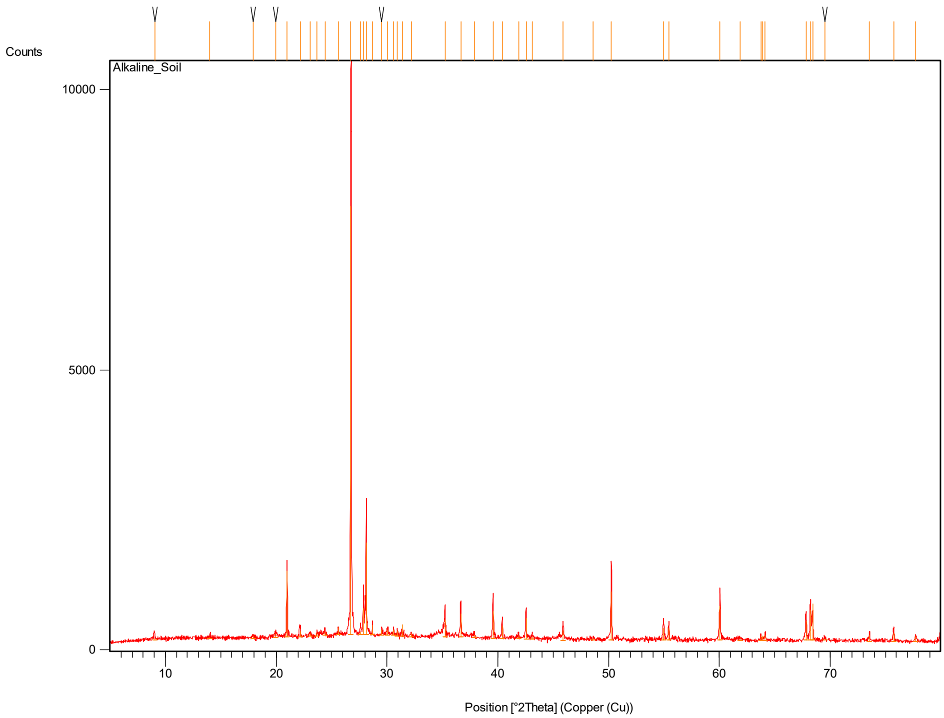
Table 2 Measurement conditions of alkaline soil

Dataset name	*Alkaline soil*
Comment	Configuration = spinner reflection-transmission, owner = User-1, creation date = 6/25/2009 11:03:49 AM
	Goniometer = PW3050/60 (theta/theta); minimum step size 2theta: 0.001; minimum step size omega: 0.001
	Diffractometer system = XPERT-PRO
	Measurement program = Thapar_Spinner stage, owner = User-1, creation date = 2/5/2010 5:38:09 PM
Measurement date/time	8/21/2015 10:26:13 AM
Start position [°2Th.]	5.0066
Operator	Administrator
Scan step time [s]	31.6200
Raw data origin	XRD measurement (*.XRDML)
Scan axis	Gonio
Offset [°2Th.]	0.0000
End position [°2Th.]	79.9906
Step size [°2Th.]	0.0130
Specimen length [mm]	10.00
PSD mode	Scanning
Irradiated length [mm]	10.00
K-alpha1 [Å]	1.54060
Scan type	Continuous
PSD length [°2Th.]	3.35
Goniometer radius [mm]	240.00
Divergence slit type	Automatic
Anode material	Cu
Measurement temperature [°C]	25.00
Incident beam monochromator	No
Generator settings	40 mA, 45 kV
Diffractometer type	0000000011059259
Diffractometer number	0
Pinning	Yes
Dist. focus-diverg. slit [mm]	100.00

4.3 Main graphics, analyse view

Figure 5 shows the analytical view of proposed evaluation.

Figure 5 Analytical view of the proposed evaluation process (see online version for colours)



4.4 Peak list

The peak list of alkaline soil is summarised in Table 3.

Table 3 Summarisation of peak list of alkaline soil

Pos. [°2Th.]	*Height [cts]*	*d-spacing [Å]*	*Rel. int. [%]*	*Area [cps*°2Th.]*	*Area [cts*°2Th.]*	*FWHM [°2Th.]*
9.0334	0.28	9.78156	0.00	0.61	19.32	4.0000
13.9779	12.81	6.33063	0.17	0.41	13.11	0.8189
17.9232	41.87	4.94503	0.55	0.36	11.24	0.2002
19.9649	68.96	4.44370	0.90	0.90	28.53	0.3156
20.9903	1,169.86	4.22887	15.31	5.19	164.22	0.0859
22.1652	84.93	4.00730	1.11	0.28	8.72	0.0577
23.0884	42.21	3.84911	0.55	0.49	15.43	0.2746
23.7197	55.64	3.74808	0.73	0.31	9.78	0.1152
24.4165	62.94	3.64268	0.82	0.38	12.12	0.1273
25.6236	125.98	3.47374	1.65	0.55	17.46	0.0812

Table 3 Summarisation of peak list of alkaline soil (continued)

Pos. [°2Th.]	*Height [cts]*	*d-spacing [Å]*	*Rel. int. [%]*	*Area [cps*°2Th.]*	*Area [cts*°2Th.]*	*FWHM [°2Th.]*
26.7615	7,639.72	3.32856	100.00	52.41	1657.34	0.1418
27.6426	33.92	3.22443	0.44	1.27	40.09	0.0010
27.8863	466.72	3.19681	6.11	2.51	79.39	0.1063
28.1408	1,637.06	3.16847	21.43	5.43	171.56	0.0541
28.6901	166.91	3.10904	2.18	0.50	15.87	0.0496
29.5416	84.58	3.02133	1.11	0.62	19.47	0.1614
30.0707	99.82	2.96937	1.31	1.54	48.71	0.3724
30.5981	95.39	2.91938	1.25	0.60	19.08	0.1397
30.9672	84.70	2.88542	1.11	0.69	21.82	0.1811
31.4244	211.17	2.84447	2.76	0.84	26.66	0.0696
32.1944	54.74	2.77818	0.72	0.64	20.34	0.2675
35.2444	292.92	2.54443	3.83	1.37	43.48	0.0823
36.6621	418.70	2.44922	5.48	2.30	72.61	0.0982
37.8990	44.72	2.37209	0.59	0.86	27.29	0.4555
39.5870	472.12	2.27474	6.18	2.23	70.59	0.0813
40.4138	219.27	2.23009	2.87	1.13	35.76	0.0881
41.8898	49.88	2.15486	0.65	1.12	35.50	0.5402
42.5647	361.35	2.12225	4.73	1.94	61.49	0.0950
43.1510	50.06	2.09476	0.66	0.86	27.09	0.4146
45.9207	174.79	1.97465	2.29	1.45	45.91	0.1563
48.5905	7.24	1.87221	0.09	0.84	26.53	2.9130
50.2585	865.21	1.81391	11.33	4.77	150.67	0.0936
54.9833	200.31	1.66869	2.62	1.24	39.29	0.1049
55.4395	196.62	1.65603	2.57	1.14	36.06	0.0978
60.0675	598.12	1.53903	7.83	3.77	119.34	0.1054
61.8963	43.06	1.49787	0.56	1.63	51.55	0.9018
63.7615	79.10	1.45848	1.04	0.27	8.53	0.0615
63.9247	82.45	1.45515	1.08	0.43	13.67	0.1631
64.1059	101.35	1.45147	1.33	0.57	18.02	0.1329
67.8377	325.55	1.38042	4.26	2.08	65.79	0.1095
68.2310	541.62	1.37342	7.09	2.84	89.89	0.0950
68.4298	637.19	1.36991	8.34	3.90	123.33	0.1775
69.5099	1.71	1.35124	0.02	0.57	17.97	0.0010
73.5529	98.44	1.28663	1.29	0.72	22.78	0.1225
75.7440	152.26	1.25476	1.99	1.02	32.21	0.1109
77.7615	82.52	1.22717	1.08	0.66	20.84	0.1335

4.5 Pattern list

Table 4 summarises the pattern list of alkaline soil.

Table 4 Pattern list summarisation of alkaline soil

Visible	*Ref. code*	*Score*	*Compound name*	*Displacement [°2Th.]*	*Scale factor*	*Chemical formula*	*Semiquant [%]*
*	01-070-3755	64	Quartz	0.129	0.975	SiO_2	85
*	01-070-3752	47	Albite	0.078	0.039	(Na0.98 Ca0.02)	15

5 Tiles dust

5.1 Measurement conditions

The measurement condition of tiles dust is given in Table 5.

Table 5 Measurement condition of tiles dust

Dataset name	*Tile dust*
Operator	Administrator
Comment	Configuration = spinner reflection-transmission, owner = User-1, creation date = 6/25/2009 11:03:49 AM Goniometer = PW3050/60 (theta/theta); minimum step size 2theta: 0.001; minimum step size omega: 0.001 Sample stage = reflection-transmission spinner PW3064/60; minimum step size phi: 0.1 Diffractometer system = XPERT-PRO Measurement program = Thapar_spinner stage, owner = User-1, creation date = 2/5/2010 5:38:09 PM
Measurement date/time	8/21/2015 11:26:56 AM
Start position [°2Th.]	5.0066
Divergence slit type	Automatic
Raw data origin	XRD measurement (*.XRDML)
Step size [°2Th.]	0.0130
Scan axis	Gonio
Scan step time [s]	31.6200
End position [°2Th.]	79.9906
PSD mode	Scanning
PSD length [°2Th.]	3.35
Scan type	Continuous
Irradiated length [mm]	10.00
Offset [°2Th.]	0.0000
Measurement temperature [°C]	25.00
Specimen length [mm]	10.00

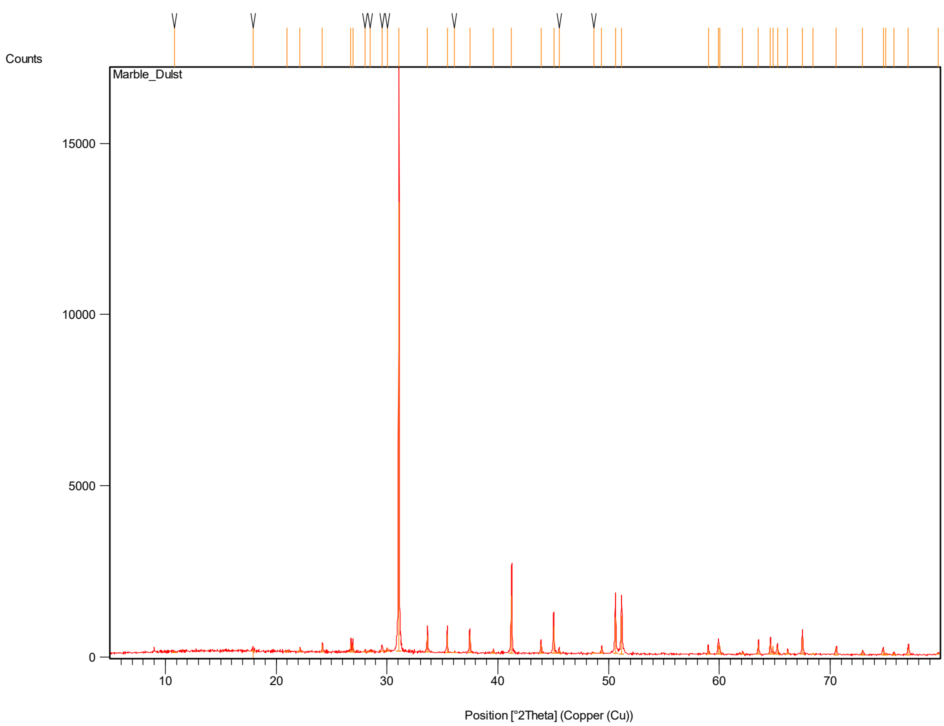
Table 5 Measurement condition of tiles dust (continued)

Dataset name	*Tile dust*
Generator settings	40 mA, 45 kV
K-alpha1 [Å]	1.54060
Anode material	Cu
Diffractometer number	0
Diffractometer type	0000000011059259
Goniometer radius [mm]	240.00
Spinning	Yes
Incident beam monochromator	No
Dist. focus-divers. slit [mm]	100.00

5.2 Main graphics, analyse view

Figure 6 shows the diagrammatic analytical view of tiles dust.

Figure 6 Analytical view of tiles dust (see online version for colours)



5.3 Peak list

The peak list of tiles dust is in Table 6.

Table 6 Peak list of tiles dust

Pos. [°2Th.]	*Height [cts]*	*d-spacing [Å]*	*Rel. int. [%]*	*Area [cps*°2Th.]*	*Area [cts*°2Th.]*	*FWHM [°2Th.]*
10.7915	6.44	8.19166	0.05	1.82	57.64	4.0000
17.9184	–189.95	4.94634	–1.45	0.21	6.50	0.0013
20.9698	42.22	4.23295	0.32	0.16	4.95	0.0701
22.1485	108.97	4.01029	0.83	0.31	9.89	0.0463
24.1809	193.17	3.67762	1.47	1.06	33.37	0.1100
26.7561	240.08	3.32922	1.83	1.11	35.03	0.0884
26.9303	207.48	3.30808	1.58	0.93	29.49	0.0888
28.0120	0.58	3.18274	0.00	0.18	5.77	0.0013
28.5175	26.18	3.12746	0.20	0.26	8.12	0.2184
29.5453	0.22	3.02097	0.00	0.71	22.46	0.0013
30.0487	104.68	2.97149	0.80	0.22	6.92	0.0302
31.0849	13,109.28	2.87476	100.00	53.17	1681.28	0.0707
33.6600	481.87	2.66049	3.68	2.40	76.01	0.0885
35.4429	512.26	2.53064	3.91	2.76	87.20	0.0954
36.0779	26.75	2.48754	0.20	0.19	6.14	0.1535
37.4861	490.63	2.39726	3.74	2.88	91.17	0.1046
39.6042	90.72	2.27379	0.69	0.46	14.60	0.0865
41.2565	1,664.12	2.18647	12.69	9.64	304.87	0.1003
43.9209	237.62	2.05981	1.81	1.57	49.78	0.1169
45.0548	788.77	2.01057	6.02	4.34	137.29	0.0931
45.5525	101.27	1.98975	0.77	0.50	15.71	0.0876
48.6602	11.99	1.86969	0.09	0.21	6.59	0.4118
49.3848	149.42	1.84394	1.14	1.11	34.95	0.1311
50.6352	1,065.81	1.80130	8.13	7.22	228.31	0.1184
51.1831	1,117.10	1.78329	8.52	7.90	249.91	0.1249
59.0090	123.19	1.56408	0.94	1.02	32.32	0.1451
59.9217	246.18	1.54242	1.88	1.91	60.42	0.1363
60.0760	253.54	1.53883	1.93	0.64	20.20	0.0921
62.0992	57.40	1.49346	0.44	0.47	14.74	0.1393
63.5338	255.92	1.46315	1.95	1.87	59.11	0.1241
64.6218	304.10	1.44112	2.32	2.32	73.36	0.1305
64.8600	229.57	1.43640	1.75	0.61	19.20	0.0724
65.2466	175.00	1.42883	1.33	1.41	44.45	0.1404
66.1775	94.04	1.41097	0.72	0.69	21.82	0.1240
67.5028	459.25	1.38645	3.50	3.21	101.58	0.1168
68.4211	33.24	1.37006	0.25	0.12	3.89	0.0614
70.5629	143.77	1.33364	1.10	1.36	43.10	0.1630
72.9407	87.65	1.29591	0.67	0.68	21.51	0.1302
74.7977	106.89	1.26827	0.82	1.13	35.82	0.1847
75.0275	73.15	1.26496	0.56	0.15	4.71	0.1655
75.7615	51.52	1.25452	0.39	0.31	9.85	0.1014
77.0730	167.71	1.23641	1.28	1.60	50.71	0.1621
79.7728	1.57	1.20121	0.01	0.01	0.45	0.0013

5.4 Pattern list

Table 7 shows the pattern list of tiles dust.

Table 7 Pattern list of tiles dust

Visible	*Ref. code*	*Score*	*Compound name*	*Displacement [°2Th.]*	*Scale factor*	*Chemical formula*	*SemiQuant [%]*
*	01-083-1766	78	magnesium calcium bis(carbonate)	0.125	0.814	$MgCa(CO_3)_2$	98
*	03-065-0466	30	Quartz low, syn	0.101	0.022	O_2Si	2

5.5 Chemical test

The chemical test is performed in CSSRI lab Karnal. The soils are mixed with tile dust with a different variation. Before testing the sample, the sample is prepared before 30 days ago. The sample is prepared in different conditions. The sample is put in saturated condition for 30 days. The parallel samples are put in submerged condition for 30 days. The sample mixing is shown in Table 8. The representation of soil samples is given in Figure 7.

Table 8 Combinations of soil sample that put in container

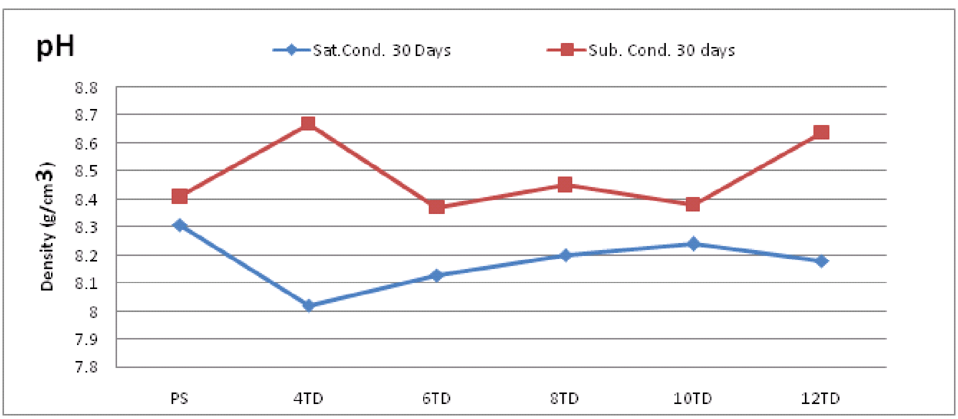
Sr no.	*SAMPLE*	*Combination*	*Combination (gm)*
1	Sample-1	Parent soil	SOIL-250 gm
2	Sample-2	TD-4% + SOIL	TD-10 gm + SOIL-240 gm
3	Sample-3	TD-6% + SOIL	TD-30 gm + SOIL-235 gm
4	Sample-4	TD-8% + SOIL	TD-20 gm + SOIL-230 gm
5	Sample-5	TD-10% + SOIL	TD-25 gm + SOIL-225 gm
6	Sample-6	TD-12% + SOIL	TD-30 gm + SOIL-220 gm

Figure 7 Representation of soil samples (see online version for colours)

5.6 Effect of pH

The variation of pH with alkaline soil and tile dust treatment is shown in Figure 8. The pH of the samples treated with tile dust for 4 to 12% is found to increase from 6.88 to 8.72, respectively. A low pH generally enhances a positive edge to negative surface interaction, thereby leading to flocculation from the suspension. A higher pH environment resulting from the addition of more tile dust to the contaminated soil will promote the dissociation of calcium cations supplied by the tile dust to replace the cations normally present on the surface of the clay mineral. This increase in pH could be due to hydroxides which are created due to the dissolution of oxides in the contaminated soil-tile dust mixtures used. It might also be due to the removal of free lime from the tile dust; which chemically is a base and will assist in neutralising acidic ions contained in the contaminated soils. This further increases the alkalinity and hence the pH. The tile dust has a pH value of 9.39, which is higher than that of the contaminated soil (6.88). The tannery effluent has a pH of 8.7 while the natural soil has a pH of 6.67. When the soil was contaminated, a slightly higher pH was obtained as a result of salts present in the effluent.

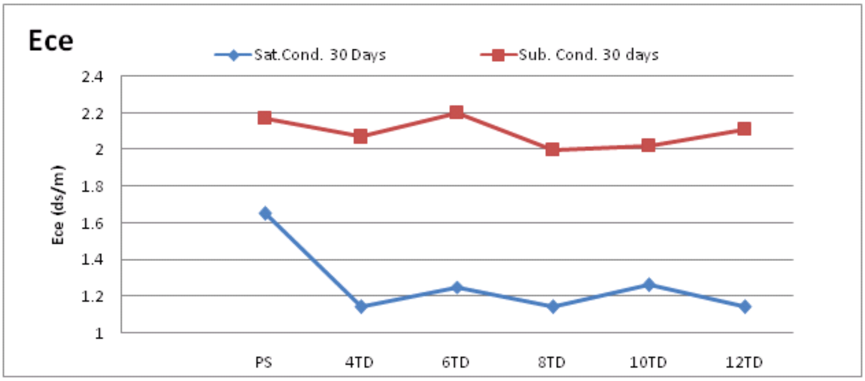
Figure 8 Variation of pH with alkaline soil and tile dust treatment (see online version for colours)



5.7 Effect of electrical conductivity

Soil electrical conductivity is an indirect measurement that correlates very well with several soil physical and chemical properties. Electrical conductivity is the capability of a material to conduct (transmit) an electrical current, and it is commonly expressed in units of milliSiemens per metre (mS/m). Alternatively, electrical conductivity measurements can be expressed in deciSiemens per metre (dS/m), which is 100 times greater than milliSiemens per metre. This is illustrated in Figure 9.

Figure 9 Effect of ECe (see online version for colours)

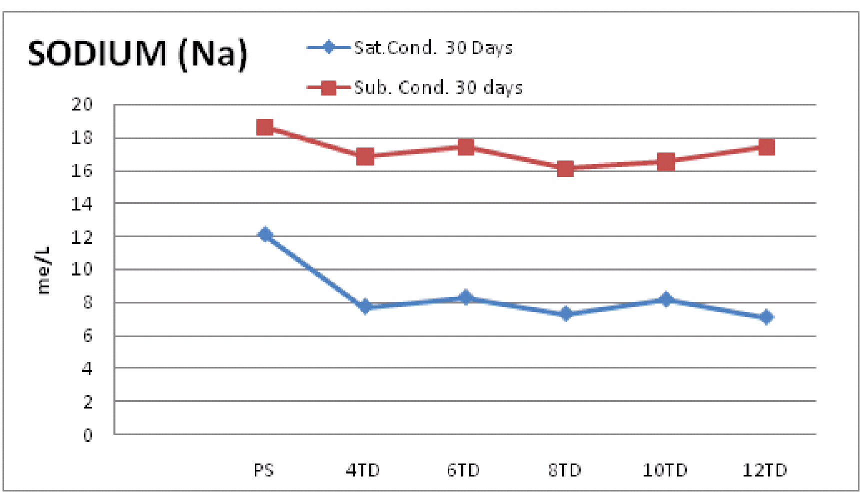


5.8 Effect of sodium (Na)

On soil, sodium gives the opposite impact of salinity. The primary physical processes associated with high sodium concentrations are soil dispersion and clay platelet and aggregate swelling. The forces, which together bind clay particles, are disrupted if there have more sodium ions among them. While occurring this separation, the clay particles cause swelling, expand, and soil dispersion.

Soil dispersion causes clay particles to plug soil pores, resulting in reduced soil permeability. When soil is repeatedly wetted and dried, and clay dispersion occurs, it then reforms and solidifies into almost cement-like soil with little or no structure. The effect of sodium is in Figure 10.

Figure 10 Effect of sodium (see online version for colours)

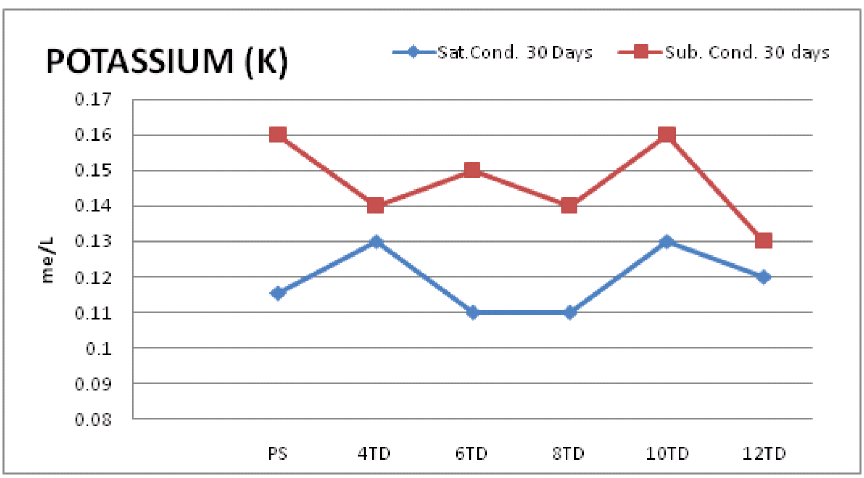


5.9 Effect of potassium (K)

In fact, potassium (K) is the same as the phosphorus (P), since it is identified as the various availability counts or 'pools' in the soil. The available status changes since they move towards among pools. Further, the pools for K are mentioned as: exchangeable (less available), soil solution (very available), fixed (rarely available) and non-exchangeable (hardly available) (Figure 9). In soil solution, the dissolved K ions are willingly taken up through crop roots, which are generally included among 2 to 5 mg/l in normal agricultural soils. For P, the obtainable forms are normally exist as orthophosphate. However only little amounts is held in soil water, normally only about 0.05 mg/l or 1–2% of total P. Hence, the fixed form of P is very crucial to increase the availability of soil P to the crop.

Since the clay particles/lattices have a negative surface charge, they are reminded to be the positively charged particles, including K^+ ions. The respective K+ ions could be eliminated bit easily by some other same charged ions, and therefore available for moving into the soil solution that to be taken up via crop roots. Here, the non-exchangeable pool includes minimal available K^+ ions, which becomes strongly attached to the clay particles. The effect of potassium is in Figure 11.

Figure 11 Effect of potassium (see online version for colours)

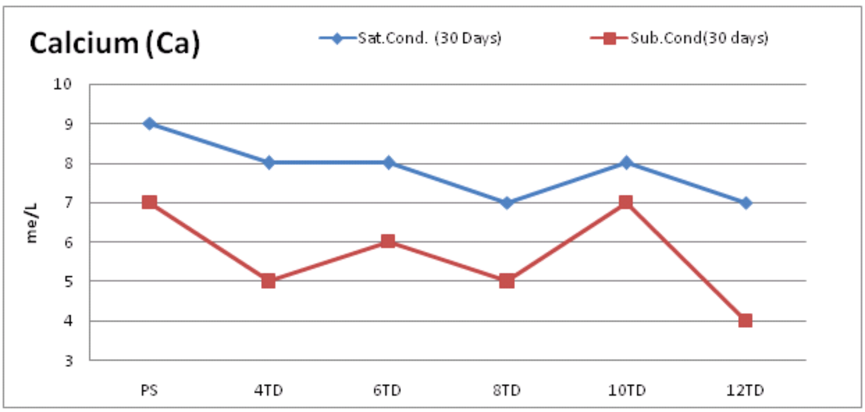


5.10 Effect of calcium (Ca)

In the experimental time, the preparation of standard calcium solution is done by dissolving the reagent-grade calcium carbonate (oven-dried) that is of 2.4972 grams in a solution including about 8 millilitres of concentrated hydrochloric acid and 500 millilitres of distilled water. This respective solution gets diluted to 1,000 millilitres along 0.10 normal hydrochloric acids and also includes 1,000 parts/million of calcium. The preparation of five standard reference solutions including 0, 50, 100, 150, and 200 parts/million of calcium is done through the measurement of 0, 25, 50, 75, and 100 millilitres of solution including 1,000 parts/million of calcium and has transferred these solutions to 500-millilitre volumetric flasks. Further, the calcium standards get diluted to the volume of 500 millilitres along 0.10 of normal hydrochloric acid.

The determination of calcium concentration in the soil solution extract is defined via the Beckman Model DU Flame Spectrophotometer. Further, the measurement of soil solution extract along with the calcium standard reference solutions are done as per the operating procedure Instruction Manual for the Beckman Model DU Flame Spectrophotometer (7). In the extracted soil solution, the amount of calcium is also defined through the referring of calibration curve that was attained by plotting the percent transmittance readings over the calcium concentration of five reference solutions. Maximum value is attained at 10% of TD, which is also the maximum value in saturated condition. Figure 12 shows the effect of calcium.

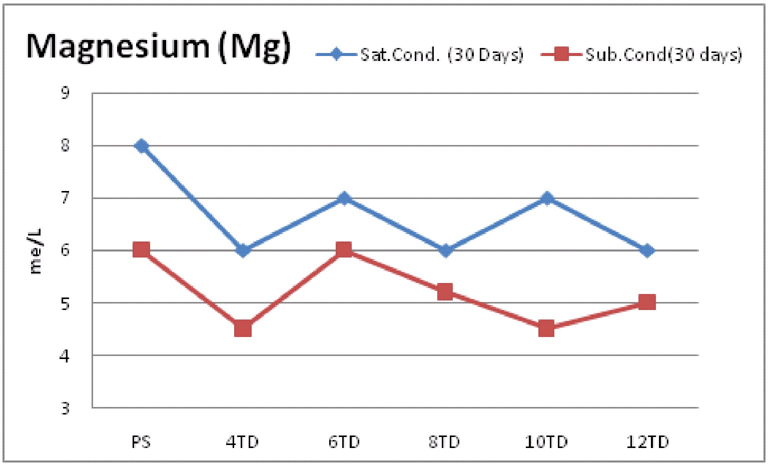
Figure 12 Effect of calcium (see online version for colours)



5.11 *Effect of magnesium (Mg)*

The solution of standard magnesium is prepared through dissolving 1 gram of reagent-grade magnesium metal in a dilute hydrochloric acid solution having distilled water of 400 millilitres and concentrated hydrochloric acid of 20 millilitres. The respective solution is diluted to 1,000 millilitres along distilled water, which includes 1,000 parts/million of magnesium. Further, the preparation of solution including 100 parts/million of magnesium is done by diluting 100 millilitres of the magnesium solution (1,000-parts-per million) to 1,000 millilitres of distilled water. This solution includes magnesium (100 parts/million) serves as a stock solution, where the preparation of other standard magnesium solutions would carry out. The preparation of five standard reference solutions like 0, 5, 10, 15, and 20 parts/million are done through the measurement of 0, 25, 50, 75, and 100 millilitres of a solution, which includes 100 parts/million of magnesium and subsequently transfers to 500-millilitre volumetric flasks. Procedure: the magnesium concentration in the soil solution extract is also defined along the Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer. Figure 13 shows the graphical representation of the impact of magnesium.

Figure 13 Effect of magnesium (see online version for colours)



6 Conclusions

From the present study, the performances of industrial waste material tile dust in road construction were studied through laboratory examination. The alkaline soil admixed with tile dust samples was cured up 4 to 7 days before testing. Different tests including SPT, CBR, UCS, and X-RD, pH, ECe, Na, K, Mg, Ca chemical test were performed (for chemical test 0 to 30 days). The conclusions of this investigation are given below:

1 The investigation has observed the marked enhancements in standard Proctor test for soil admixed with TD, and the enhancement was more definite for 8% TD.

2 Admixing of TD has been made to have greater optimum moisture content as the stabilisers dosages, which has maximised from.4 to 6%.

3 Admixing of TD has increased the CBR value of alkaline soil up to 12% at 4 curing days. The value of CBR values has increased abundantly under the soaking condition comparing to unsoaked condition. In the soaking condition, the TD gives the greater value up to 8% TD and in unsoaked condition 10 % TD has given the higher values.

4 Admixing of TD in alkaline soil for UCS Test (1, 4 and 7 days) has been observed. At 4 days, 8% TD shows higher values while comparing to testing after one day.

5 The XRD analysis has revealed that the alkaline soil could easily react with the particles of TD and they have also made better bonding with one another. This condition might increase the strength.

6 In the chemical test pH value that cures the sample for 30 days in saturated and submerged condition, TD minimises the impact of alkaline soil and also minimises the pH value of sample. From 6% to 8% TD percentage reduces the pH value of alkaline soil.

7 Admixing of TD for electric conductive test (ECe) under saturated condition is decreased when compared to the submerged condition. Saturated condition has attained to be effective.

8 Various chemical tests have done namely cation test sodium, potassium, calcium, magnesium and under the submerged condition, the test result values were more when compared to saturated condition. In the chemical test, 4 to10% of TD minimises the value of chemical test.

9 The TD consumption in bulk quantity in the road construction project could be performed with reducing accumulation hazard and environmental pollution of corresponding waste content.

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