

On Interaction of a Clayey Soil with Textile Dye Waste

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ABSTRACT

Influence of industrial effluents on soil, water, and air has been the subject matter of several researchers. This investigation aims at studying the influence of spent orange dye effluent from a Textile industry on a clayey soil. The soil is mixed with spent orange dye effluent and tested for Index properties and Engineering properties after varying curing periods. Influence of each component of dye effluent on soil is ascertained by another series of tests by mixing it with soil. The dye effluent and its constituents are found to induce cementation/bonding and flocculation to the soil resulting in improved engineering properties. X – Ray diffraction studies reveal that the clay minerals present in the soil react actively with dye effluent. The observed changes are explained in terms of changes brought out in chemical environment of pore fluid, pH and physico – chemical interactions between soil particles and particle groups.

KEYWORDS: Consolidation, Swelling, Atterberg limits, textile dye effluent.

INTRODUCTION

Industrial, mining, commercial and domestic activities involve generation of wastes and handling of large quantities of chemical substances. The wastes generated during these operations are generally let into the atmosphere, either treated or un-treated, leading to a source of pollution for one or more of the natural agents viz., Air, water and soil. Generally industrial wastes are discharged either treated or untreated into water bodies or over land. These industrial wastes if let over soil or accidental spillage of chemical substances may lead to changes in soil properties, causing either improvement or degradation of engineering behaviour of soil, sometimes leading to functional or structural failure of structures resting on it. Recent case histories of structural damage to industries and residential buildings resulting from chemical contamination of soils serve to emphasize the importance to be given to the problem of modification in engineering properties of soil due to chemical contamination (Sridharan et al 1981, Barbour and Yang 1993, Abdullah Assaad 1998, Sinha et al 2003, Zhang et al 2004). On the other hand, if there is an improvement in engineering behaviour of soil, there is a value addition to the industrial effluent serving the twin benefits of safe disposal of effluent and conservation of an engineering material (Bhattacharya et al 2004, Reddy Babu et al 2005).

The objective of the present investigation is to study the influence of a reactive type spent orange textile dye waste on the physical and index properties of a clayey soil. Discharge of effluent from textile industries into environment is a major concern for Civil engineers in general and environmental engineers in particular. Currently more than 9000 different types of dyes belonging to various applications and chemical classes are in use in the textile operations and other -industrial processes like food-processing, tannery, paints, plastics, pulp and paper .Most of the dyes used in the textile industry end up on finished fabric and grand 10 to 20 percent is lost in the residual effluent (Anliker, 1977) of which about 50 percent may reach the environment even after treatment (Karthikeyan, 1989). Only a few investigations considered the influence of textile dye waste on soil properties. Mallikarjuna Rao and Chinnappa Reddy (1996) reported the influence of a vat dye on physical and engineering properties of expansive clay. The pH, CEC, Compression index and swelling pressure of the soil were found to increase considerably when polluted with a vat dye waste solution.

MATERIALS AND METHODS

Soil

The Soil used in the present investigation is brought from 'Auto Nagar' near Tirupati. The area is largely covered by clayey soils. The required amount of soil is collected from the trial pits at a depth of 1m below the ground level, since the top soil is likely to contain organic matter and other foreign materials. Sufficient care has been exercised to see that the soil samples collected are fairly homogeneous. The soil is air dried after transporting to the laboratory and is pulverized with a wooden mallet. The soil so pulverized is sieved through 4.75mm sieve and stored in storage bins for further testing in laboratory.

Spent orange dye waste

The composition of spent orange dye waste from a local textile industry was reported by Srimurali (2001) and the same is presented in Table.1. All The components of the dye wastes are commercially available and the required quantity of spent orange dye waste/dye effluent is prepared in the laboratory by mixing the components of the dye waste in proportions presented in Table .1

From the table it could be seen that the orange dye is made up of three different dyes viz., Procion Brilliant Yellow, Procion Red Brown and, Procion Brilliant Blue. In order to assess the influence of each one of these three dyes on soil properties, additional three dye effluents, are prepared in the laboratory where in only one dye is mixed with the additives in proportion presented in Table 1. Each of the four dye effluent wastes so prepared is mixed with 5kg of soil separately so as to attain a moisture content of 26 percent. The four soil dye mixers so prepared are packed in polythene bags and kept in air tight containers in a room under controlled conditions. The required quantity of samples from these containers are taken out after curing periods of 2, 4,7,15, and 30 days and tested for necessary properties.

TESTS CONDUCTED

The tests conducted are broadly grouped into two series. First series of tests are conducted on untreated soil and soil treated with spent orange dye waste. The tests conducted include Atterberg limits (IS 2720 part 5:1985), pH (IS 2720 part 26:1987), one-dimensional consolidation (IS 2720 part 15: 1986) and swelling pressure by free

Table 1: The composition of spent orange dye waste from a local textile industry (After Srimurali 2001)

Sl. No	Description of the Item	Quantity (in gms) present in 5 lts of dye waste
Dyes[4c]		
1	Procion Brilliant yellow M4G; C.I. Reactive yellow 22; Monoazo	0.163
2	Procion Red Brown H4R; C.I.Reactive Brown 9; Monoazo	0.062
3	Procion Brilliant Blue MR; C.I. Reactive Blue 4; Anthraquinone	10.208
Additives[4c]		
4	Caustic soda (NaOH)	1.500
5	Hydrogen peroxide (H ₂ O ₂)	0.500
6	Soda ash (Na ₂ CO ₃)	80.000
7	Hydrochloric acid (HCl)	2.000
8	Lisspol paste	4.000

swell method (IS 2720 part 41 1977). Swelling pressure and consolidation characteristics viz., compression index and co-efficient of consolidation are determined by conducting one dimensional consolidation tests on statically compacted soil samples at a dry density of 16kN/m³. All these

properties are determined after curing periods of 2, 4, 7, 15, and 30 days on treated soil. A second series of tests are conducted to determine the same set of properties after 2, 4, 7, 15, and 30 days of curing period but on mixtures of soil and each of the three constituent dye components of the spent orange dye waste in isolation. This series of tests are intended to study the impact of each one of the three constituent dyes i.e. (Procion Brilliant Yellow, Procion Red Brown, and Procion Brilliant Blue) of spent orange dye waste on soil properties.

X-ray diffraction studies

X-Ray diffraction studies are conducted on untreated soil and the four soil dye waste mixtures after a curing period of 15 days. Powder samples taken from suspension are used for this purpose. The details of powder sample preparation are given elsewhere (Tirumala Rao 2004, Rajasekaran 1993).

RESULTS AND DISCUSSIONS

Properties of the soil

The soil used in this investigation is tested for its physical identification and classification properties. The properties of the soil are summarized in Table.2 According to Indian standard soil classification system (IS: 1498; 1970) the soil may be classified as clay of high compressibility having a compression index of 0.23 and moderate swelling pressure of 80 kPa.

Table 2: Properties of the soil

SL.No	Property	Value
1	Gravel	0%
2	Sand	8%
3	Silt and Clay	92%
4	Liquid limit	58%
5	Plastic limit	24%
6	Plasticity index	34%
7	I.S. Classification of soil	CH
8	pH	8
9	Compression index, C_c	0.23
10	Swelling pressure, p_s	80 kN/m ²

Influence of dye effluents on soil properties

Influence on pH

Fig.1 shows the variation of pH with curing period for the four dye soil mixtures studied. Initially pH value of untreated soil is 8. It is slightly alkaline in nature. In all the cases the pH is found to decrease up to two days of curing. However the pH increases later on from two days to seven days and remained almost constant after 7 days of curing. Compared to untreated soil pH, pH values of dye waste treated soils are less irrespective of curing period. A low pH promotes a positive edge to negative surface interaction often leading to flocculated structure. Change in structure is known to affect the engineering properties of soils (Mitchell 1993). In general flocculate structure leads to

isotropy and increase in coefficient of permeability. Change in pH indicates that there is an interaction between soil and dye effluent which could influence the engineering performance of the soil.

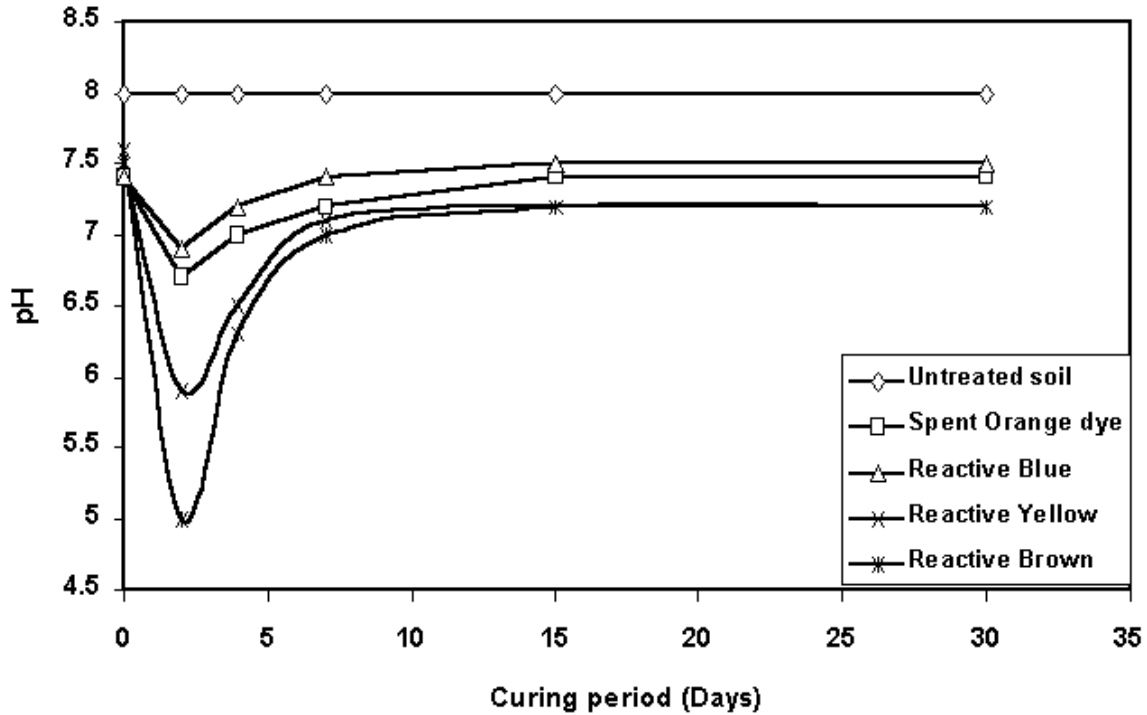


Fig.1 pH vs Curing period

Influence on liquid limit

Figs. 2 presents the variation of liquid limit with curing time for spent orange dye waste as well as for the three constituent dyes of spent orange dye waste. The liquid limit of untreated soil is 58. There is a sharp raise in liquid limit from 58 to 67 immediately after the addition of spent orange dye waste. For individual dye components also the liquid limit has raised to a value ranging from 58 to 80. However with time a sharp reduction in liquid limit is observed for all the cases. The liquid limit has come down to its original value after a curing period of 7 to 15 days and later on remained almost constant. Addition of dyes to the soil would result in changes in pore fluid chemistry leading to physico - chemical interactions between the individual particles and particle groups. Some times the chemicals added may lead to replacement of cations, or surface held anions getting into the solution or gluing of clay particles and particle groups or formation of new chemical compounds either amorphous or crystalline leading to possible changes in diffused double layer thickness. Any of these actions could result in changes in physico - chemical interactions between the particles and particle groups. These changes are likely to be reflected by variations in engineering properties as well as Atterberg limits. One or some of these changes should have taken place when the dye wastes are mixed with the soil leading to the observed changes in liquid limit.

The observed changes in liquid limit may be attributed to NaCl that is present in dye waste and Zinc that is known to be present in reactive dyes (Srimurali 2001). Sodium is likely to adsorb on to the clay particles immediately as it is present in fairly high concentration. Na⁺ being monovalent increases the double layer thickness and liquid limit as well. The observed increase in liquid limit up to two days may be attributed to adsorption of sodium on to clay particles. On the other hand, Zinc metal that is present in dye mix could reduce the liquid limit if adsorbed on to clay particles as it is divalent. Zinc is known to dissolve in water at low pH values (Zhang, 2004). The pH is observed to decrease with curing period for soil treated with dye wastes. Hence at greater curing period Zinc is likely to be dissolved in water and adsorbs on to clay which may be the reason for observed decrease in liquid limit with curing period.

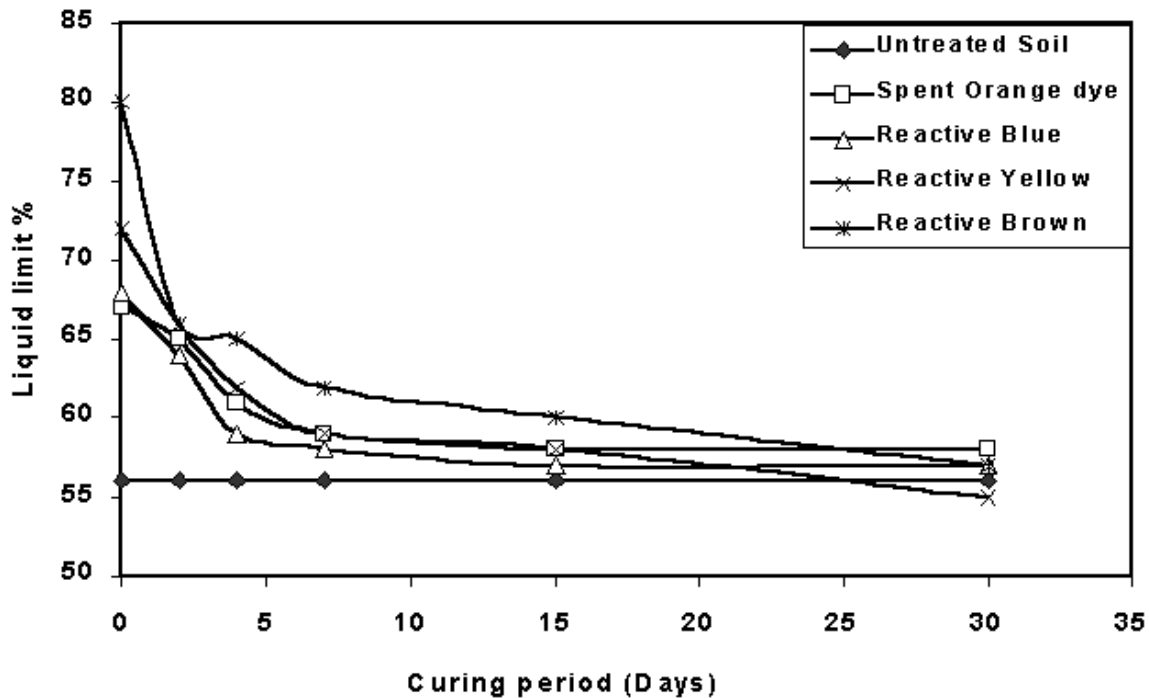


Fig. 2 Liquid limit vs Curing period

Influence on plastic limit

Plastic limit is another index property which reflects the presence of clay minerals in the soil. A change in physico-chemical environment in the soil mass shall result in change in the plastic limit as well. Fig. 3 shows the typical variation of plastic limit with curing time for the four soil dye waste mixtures. A sharp reduction in plastic limit is observed immediately after addition of dye waste followed by increase in plastic limit with time after 48 hours of curing period. The ultimate plastic limit is approximately equal to plastic limit of the original soil and is becoming asymptotic to X-axis after 15 days of curing. These observations are in tune with the observed changes in liquid limit indicating a change in physico-chemical environment and formation of new chemical compounds due to the addition of dye wastes.

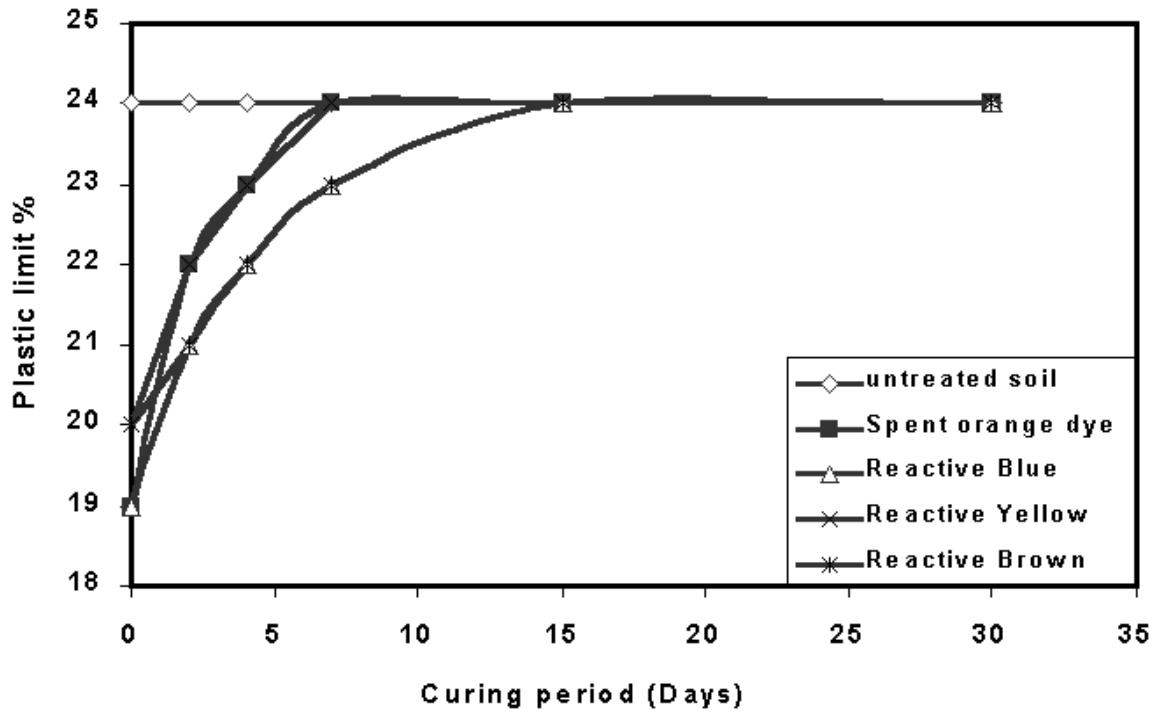


Fig. 3 plastic limit vs Curing period

Influence on plasticity index

The difference between liquid limit and plastic limit i.e., the plasticity index is an indicative of type and amount of clay and is considered as an important index derived from Atterberg limits. Fig. 4 depicts the variation of plasticity index with curing period. The plasticity index increases sharply immediately after addition of dye wastes up to 48 hours and reduces slightly there after for curing periods of 2 days, 4 days, 7 days, 15 days and 30 days. The plasticity index is fairly constant after 15 days of curing irrespective of the dye waste added to the soil. These results also confirm that there are changes in physical and chemical environment within the soil mass due to the addition of dyes and dye wastes.

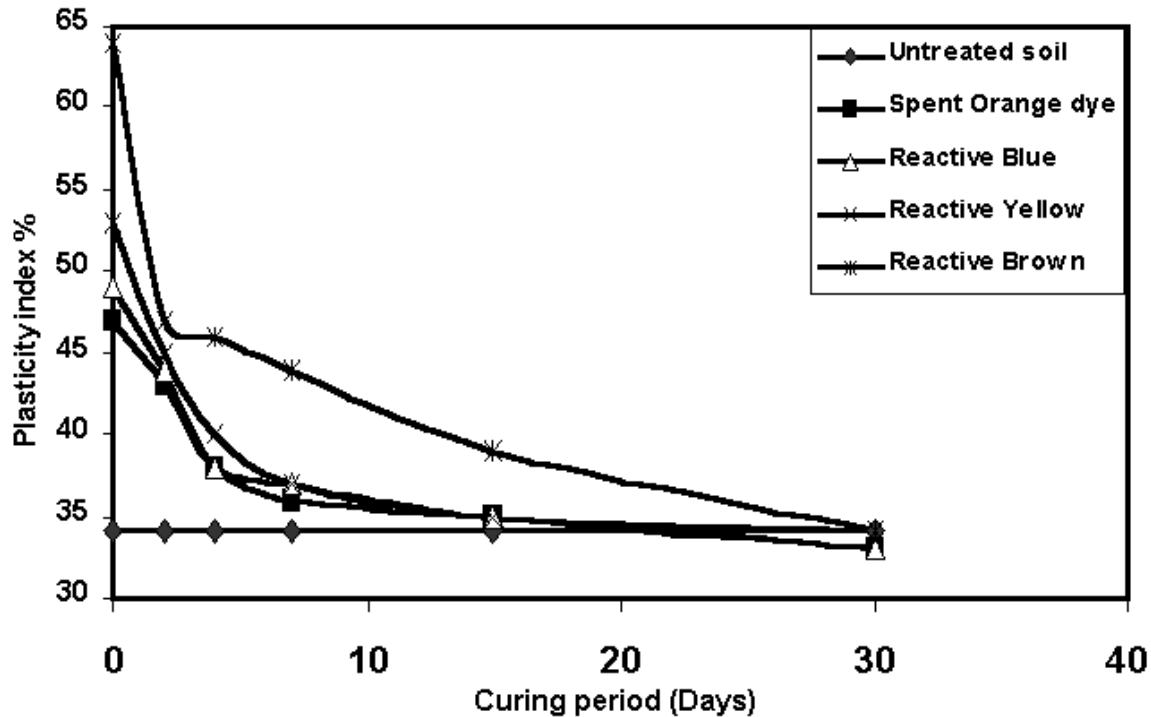


Fig. 4 Plasticity index vs Curing period

Influence on compression index

Compression index, defined as the slope of virgin portion of e - $\log p$ curve, is one of the important compressibility characteristics which are useful for determination of consolidation settlement of clayey soils. It is obtained by conducting one dimensional consolidation test. Typical e - $\log p$ curves obtained from one dimensional consolidation tests on untreated soil and soil dye mixtures are shown in Fig.5 & Fig 6. Compression index obtained from e - $\log p$ plots are summarized in Table.3. The compression index of untreated soil is found to be 0.23. The $e - \log p$ plots of dye treated soil are observed to be flat up to certain pressure in the initial stages of loading, indicating induced *apparent* pre-consolidation pressure. The induced pre-consolidation pressure may be attributed to the binding action of the new reaction products formed owing to the interaction between dye and clay minerals present in the soil, which needs to be confirmed. Further the compression index is found to decrease with curing period for the case of blue and brown dyes which may be attributed to the induced cementation. Even in the case of yellow dye and spent orange dye, though the compression index is observed to increase with curing period, the final equilibrium value for the 30 days curing period is much less than the one of untreated soil. The compression index of the soil treated with spent orange dye waste is in the range of 0.05 to 0.08 which is about 1/3rd to 1/4th of the compression index of the untreated soil. To summarize, the constituent dyes and spent orange dye waste are imparting pre-consolidation pressure to the soil leading to a reduction in compression index with respect to curing period.

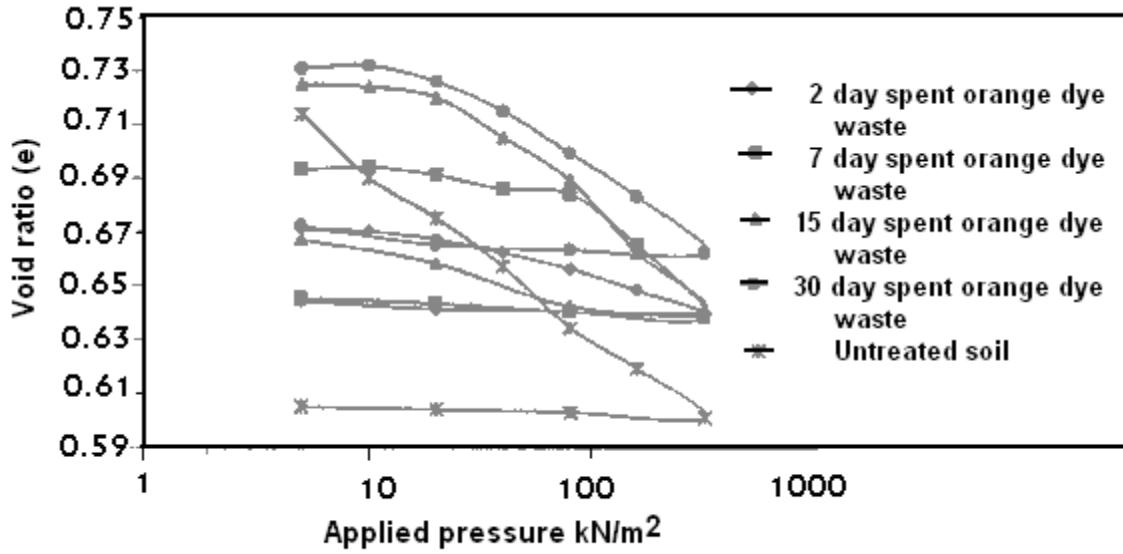


Fig. 5 Void ratio vs Applied pressure

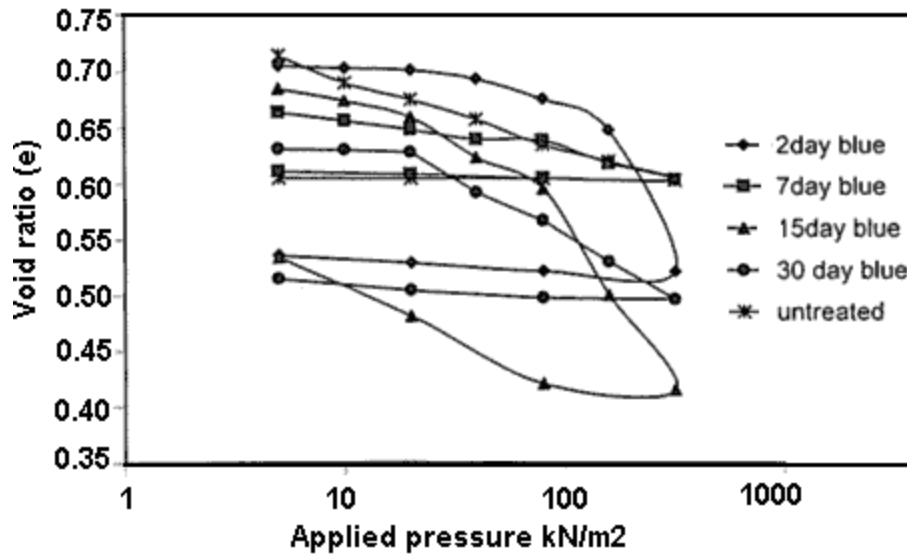


Fig. 6 Void ratio vs Applied pressure

Table 3: Compression index of soil treated with dye wastes

SL.No	Curing period (days)	Untreated soil Compression index (Cc)	Compression index (Cc)[c4]			
			Blue dye mix	Yellow dye mix	Brown dye mix	Spent orange dye mix
1	2	0.23	0.25	0.10	0.44	0.02
2	7	0.23	0.22	0.15	0.5	0.08
3	15	0.23	0.19	0.17	0.58	0.07
4	30	0.23	0.115	0.13	0.32	0.05

Influence on pre-consolidation pressure

Pre-consolidation pressure is indicative of the stress history of the soil and Casagrande proposed a method to determine pre-consolidation pressure from e-log p curve. Cementation or binding of particles does also induce similar changes to e – log p plot in which case it is termed as *apparent* pre-consolidation pressure. In the present study soils are mixed with dye effluents in the laboratory and e-log p curves are obtained by conducting consolidation tests on remoulded soil samples. Hence pre-consolidation shall not arise from stress history but from due to binding or cementing action of dye effluents or the reaction compounds formed due to physico-chemical interactions of dye effluents and soil. The e-log p plots shown in Fig.5 and Fig. 6 reveal that almost all dyes induce pre-consolidation pressure to the soil. Induced pre-consolidation pressure is determined by Casagrande's method and the Fig.7 shows the variation of pre-consolidation pressure with curing period for blue, yellow, brown and spent orange dye wastes. The pre-consolidation pressure is found to decrease with curing period for blue and brown dyes where as it is found to increase for the case of yellow and spent orange dye waste. The pre-consolidation pressure is in the range of 30 to 120 kN/m² in general, but is falling in the range of 20 to 30 kN/m² in the case of brown. The induced pre-consolidation pressure may be attributed to the cementing or binding action of reaction compounds formed due to the interaction between clay minerals and dye effluents. Since pre-consolidation pressure at the end of 30 days is about 60 to 80 kN/m², it may be presumed that cementation is weak to moderate. In case of brown dye waste, the induced pre-consolidation pressure is negligible being about 25 kN/m². The spent orange dye waste used is a reactive type of dye which is capable of forming covalent linkages with cellulose, amino, thiol and hydroxyl groups (Srimurali 2001). Also reactive dyes do contain Cl⁻ or O-SO₃Na as a leaving group enabling the dyes to form covalent bonds with fibre (Srimurali 2001). The clay minerals do contain hydroxyl groups at the surface and possibly a bonding is taking place between hydroxyls in the clay minerals and dyes or O-SO₃Na of dyes. This bonding may be responsible for the observed induced pre-consolidation pressure. Since the quantum of dyes present in dye waste is very small, the number of bonds and hence the induced pre-consolidation pressure are expected to be lesser.

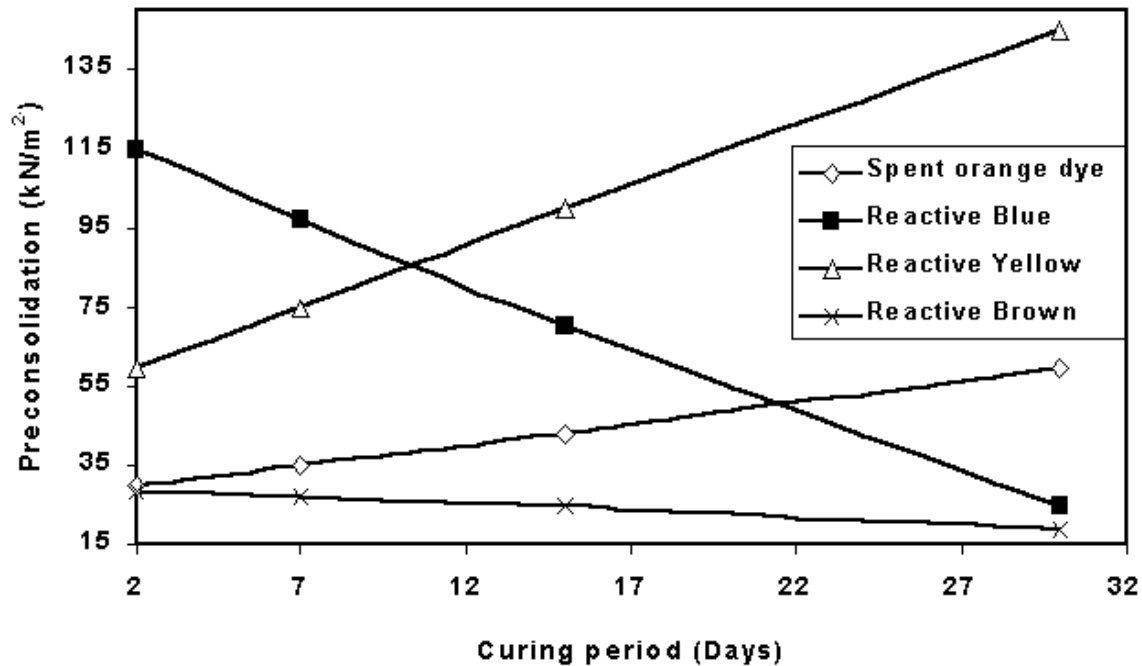


Fig.7 Pre - Consolidation vs Curing period

Coefficient of consolidation

Coefficient of consolidation indicates the combined effect of permeability and compressibility of the soil. The time for consolidation is inversely proportional to coefficient of consolidation. Fig. 8 and Fig.9 show the variation of coefficient of consolidation with curing time for the dye waste. The coefficient of consolidation for actual untreated soil is $1.098\text{cm}^2/\text{sec}$ and $0.795\text{cm}^2/\text{sec}$ for consolidation pressures of 80kN/m^2 and 160kN/m^2 respectively. The coefficient of consolidation for the soil treated with blue, yellow, brown and spent orange dye waste at 80kN/m^2 and 160kN/m^2 are obtained from consolidation test data adopting square root of time method. The coefficients of consolidation so obtained are summarized in Table 4.

Blue dye is observed to decrease coefficient of consolidation initially i.e., immediately after addition but increasing with curing period. At the end of 30 days the coefficient of consolidation is slightly lower than the one for untreated soil. Yellow dye is found to have significant influence on coefficient of consolidation. At a pressure of 80kN/m^2 , the coefficient of consolidation is $1.458\text{cm}^2/\text{sec}$ at the end of 2 days and it is gradually increased to $4.92\text{cm}^2/\text{sec}$ at the end of 30 days which is about 4 times that of the untreated soil. Similar observation can be found even at the consolidation pressure of 160kN/m^2 . Brown dye is found to have different effect on coefficient of consolidation. Initially the coefficient of consolidation rose significantly in comparison to original untreated soil but is found to decrease with curing period. However at the end of 30 days the coefficient of consolidation is only about 25 percent more than that of untreated soil.

Spent orange dye waste which is the combination of all the above three dyes is expected to have an effect which is sum total of effects of all three component dyes. The coefficient of consolidation is found to increase with time from 1.5 to $2.88\text{cm}^2/\text{sec}$ at a consolidation of pressure of 80kN/m^2 and from 0.805 to $2.32\text{cm}^2/\text{sec}$ at a consolidation pressure of 160kN/m^2 . These clearly indicate that the

coefficient of consolidation is dominantly influenced by yellow dye. An increase in coefficient of consolidation obviously indicates an increase in coefficient of permeability and rate of consolidation. The possible reason for increase in permeability may be attributed to the changes in structure that may take place owing to the interaction between clay minerals and dye wastes. Probably the reaction compounds are decreasing the repulsive forces between the clay particles imparting flocculated structure with some cementation or binding that should have been responsible for induced *apparent* pre-consolidation pressure, reduced compressibility and increased coefficient of consolidation. A low pH is said to promote a positive edge to negative surface interaction, often leading to flocculation (Mitchell, 1993). Addition of spent orange dye waste is found to decrease pH value considerably reinforcing the above proposed argument.

Swelling pressure

Untreated soil is observed to exhibit swelling when the surcharge is equal to a seating load of 5kpa. The swelling pressure is determined by free swell oedometer test and is found to be 80kpa. When the soil is treated with dyes or dye wastes no swelling is observed and hence no swelling pressure.

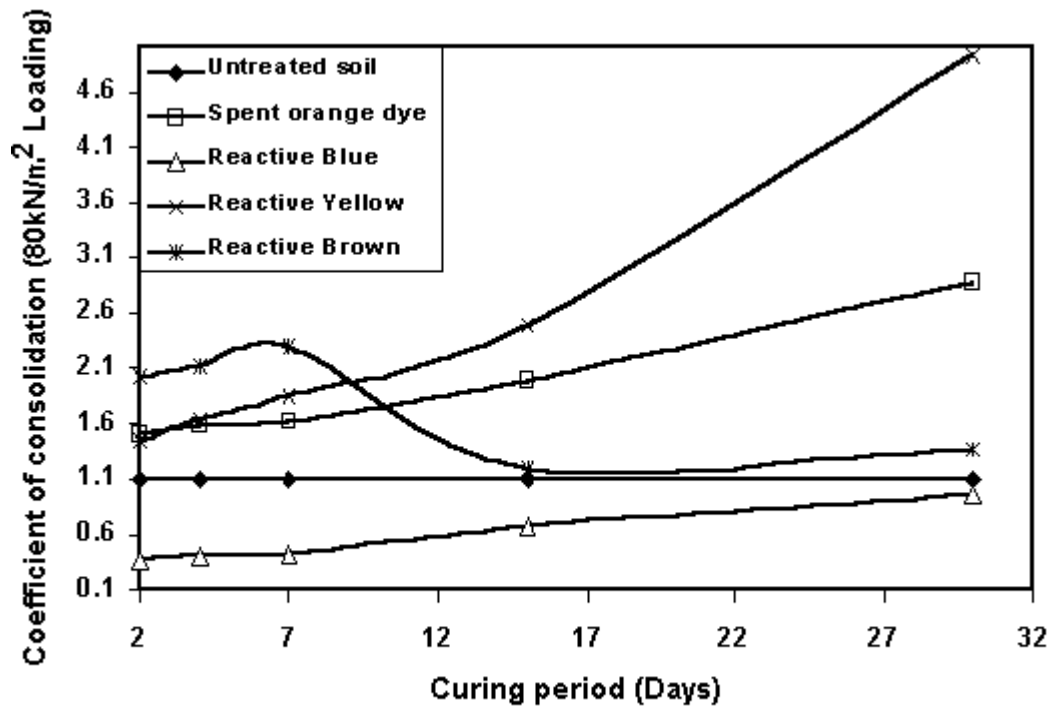


Fig. 8 Coefficient of consolidation vs Curing period

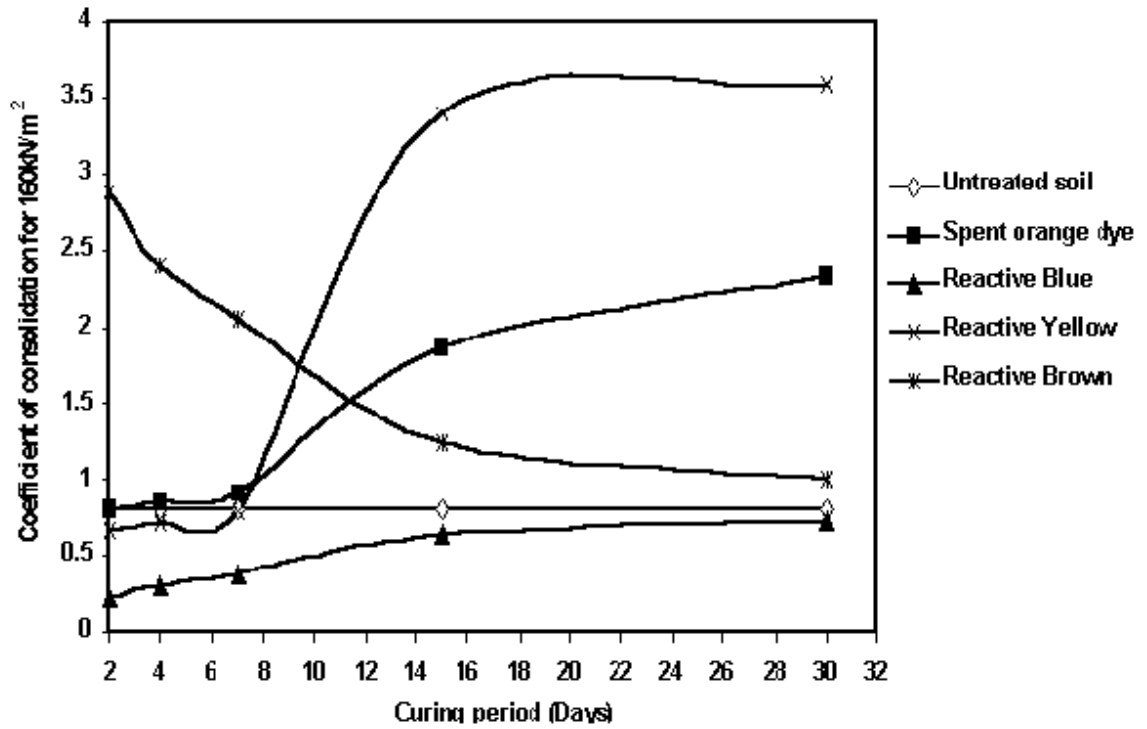


Fig.9 Coefficient of consolidation vs Curing period

Table 4: Coefficient of consolidation of soil treated with dye wastes

Sl No	Curing period (days)	Untreated soil		Spent orange dye mix		Blue dye mix		Yellow dye mix		Brown dye mix	
		@ 0.8 kg/cm ²	@ 1.6 kg/cm ²	@ 0.8 kg/cm ²	@ 1.6 kg/cm ²	@ 0.8 kg/cm ²	@ 1.6 kg/cm ²	@ 0.8 kg/cm ²	@ 1.6 kg/cm ²	@ 0.8 kg/cm ²	@ 1.6 kg/cm ²
1	2	1.098	0.795	1.513	0.805	0.378	0.232	1.458	0.657	2.038	2.88
2	7	1.098	0.795	1.62	0.903	0.42	0.371	1.852	0.79	2.2	2.05
3	15	1.098	0.795	2.0	1.85	0.684	0.629	2.5	3.4	1.2	1.242
4	30	1.098	0.795	2.88	2.32	0.96	0.72	4.92	3.6	1.37	1.0

Editor's note: The old-metric unit of 1 kg/cm² roughly equals 100 kPa

The results presented in the earlier section do indicate that some cementation or bonding is taking place within the soil mass when treated with dye wastes. This bonding should have been responsible for absence of swelling in soil treated with dye wastes.

X-ray diffraction analysis

X-Ray diffraction is the most widely used method for identification of minerals present in soil as well as to identify the new reaction products in the chemically treated soils. Several investigators used this technique in the past to investigate mineralogical changes occurred in the soil system when treated

with chemicals (Goldberg and Klein 1952, Sabry et al 1981, Rajasekaran and Narasimha Rao 1996, Bell 1996). Here also an attempt has been made to identify dye soil reaction products from XRD studies. The X-Ray diffractograms of untreated soil and soil treated with spent dye waste, blue, yellow, red brown dye effluents are shown in Figs .10 to 13 respectively. The minerals present in the untreated soil are identified as Kaolinite, Quartz, Calcite and Illite. The mineralogical analysis was carried out by comparing the XRD patterns with the standard index system reported by Brown (1961). In the soils treated with dye effluents no new peaks are found. Further, the peaks corresponding to Kaolinite and Illite are found to disappear in all the four soil dye mixtures. However, in case of blue and brown dye treated soils Quartz and Calcite peaks could be seen. The low intensities of peaks observed in the case of yellow and spent orange dye waste points to the fact that the material is primarily amorphous in nature. No new peaks are observed in any of the cases. Hence it may be concluded that the dye effluents are reacting actively with minerals present in soil and are leading to formation of amorphous substances.

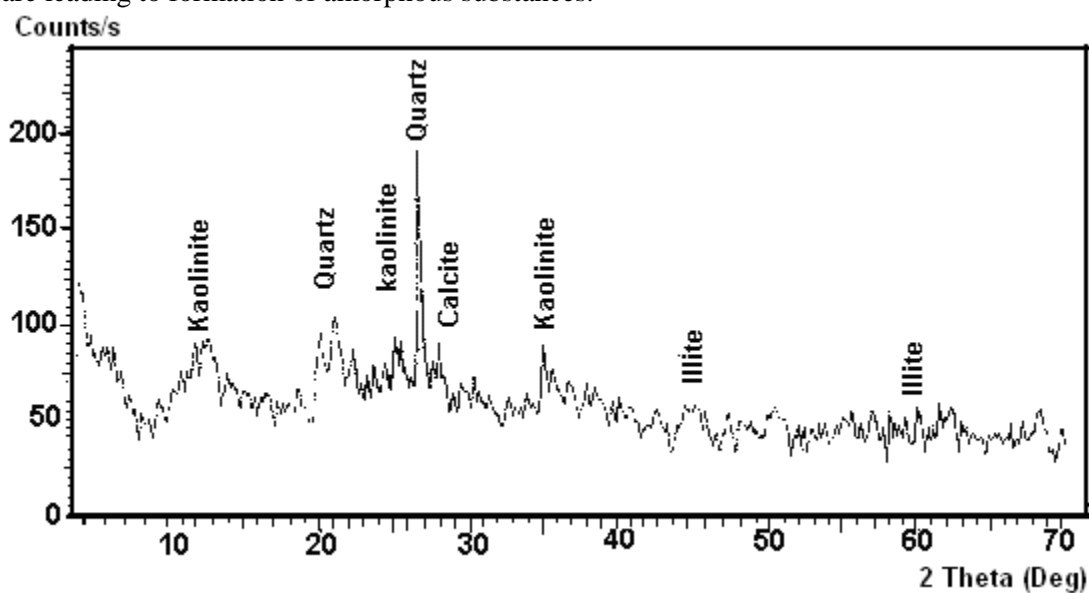
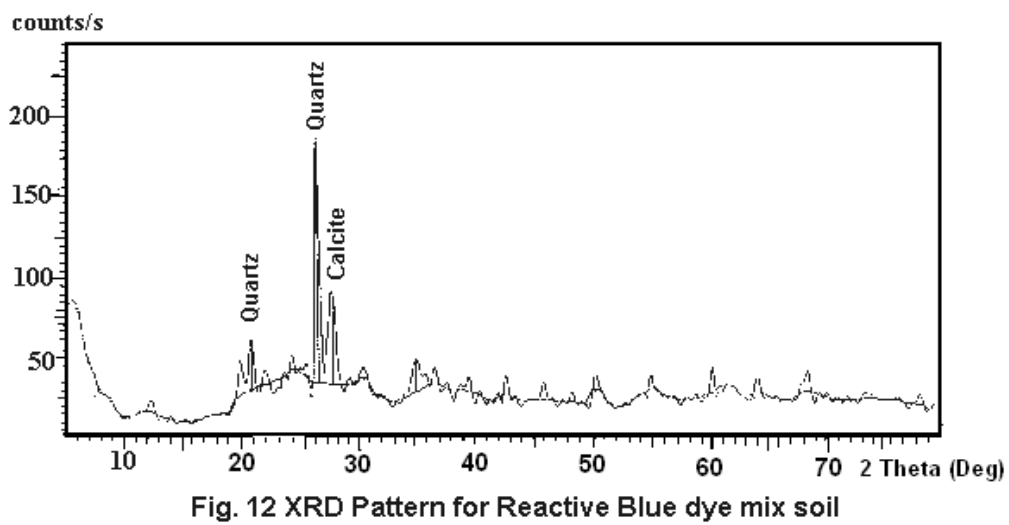
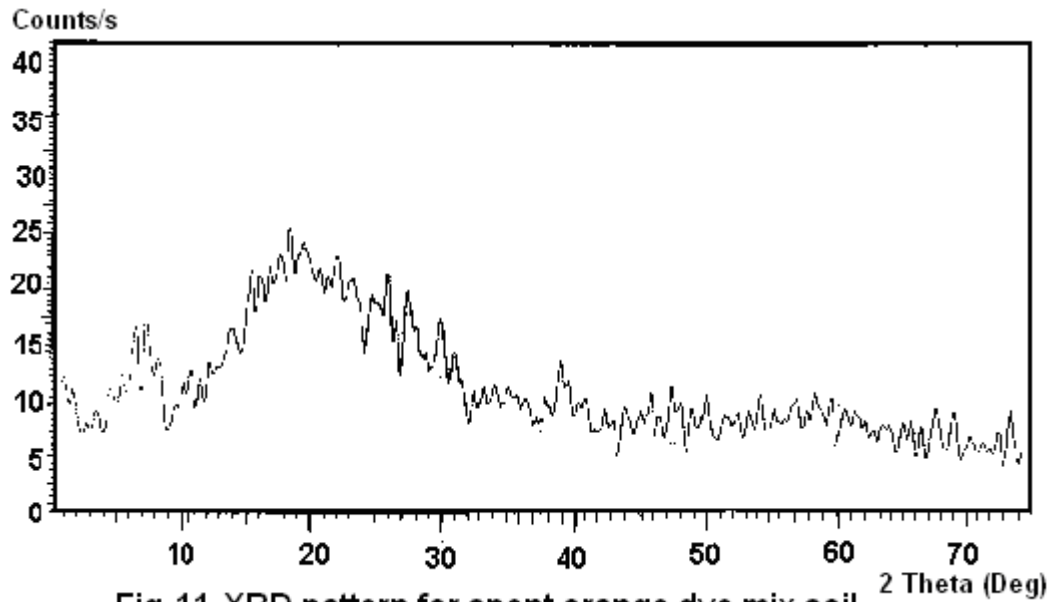


Fig.10 XRD Pattern for Untreated soil



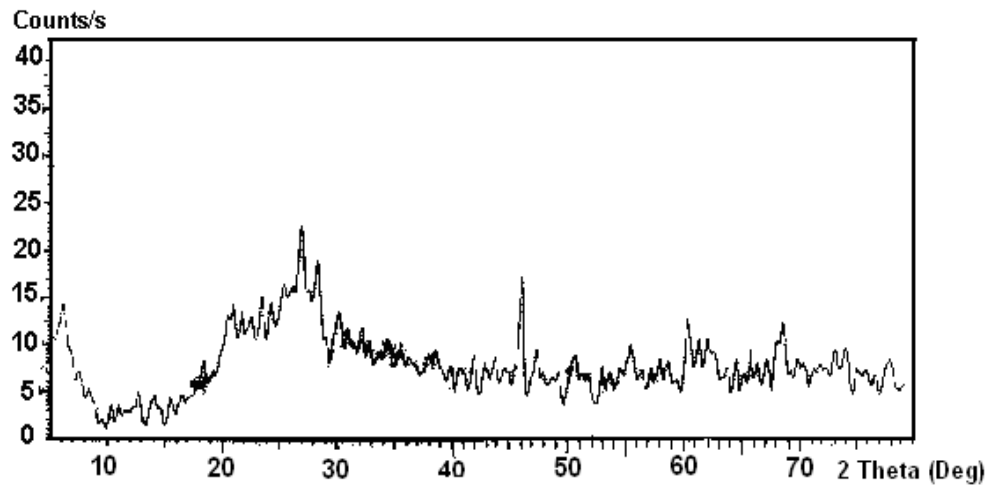


Fig. 13 XRD pattern for Reactive yellow dye mix soil

CONCLUSIONS

Industrialization added with population explosion has increased the use of pigments and dyes many-fold especially in textile industry. The influence of spent orange dye effluent from a local industry on physical and index properties of a clay soil is studied by conducting a series of tests in the laboratory. The study reveals that each of the components of spent orange dye effluent as well as spent orange dye effluent has significant influence on soil properties. The soil properties are found to depend on curing period and are getting stabilized after curing period of 7 to 15 days. The spent orange dye effluent is found to reduce compression index, increase coefficient of consolidation, reduce swelling pressure and impart *apparent* pre- consolidation pressure to the soil. The observed changes are explained in terms of binding action of dye and O – SO₃Na groups that are present in dyes with hydroxyls on the surface of clay minerals, supported by observed changes in pH, liquid limit and physico – chemical environment of the fluid. X – Ray diffraction studies reveal that the clay minerals present in soil react actively with dye effluent leading to formation of new unidentified amorphous chemical substances. The results presented in this investigation raise the hope of value addition to the reactive spent orange dye waste if mixed with soil that may be used as a construction material.

REFERENCES

1. Abdullah Assa`ad (1998) "Differential Upheaval of Phosphoric Acid Storage Tanks in Aqaba," Journal of Performance of Constructed Specialty, Vol.12, No. 5, PP 71-76.
2. Anliker (1977) "Color Chemistry and the Environment," Rev. Prog. Coloration, Vol. 8, No. 60 (Cited by Srimurali 2001).
3. Barbour, S.I, and N. Yang (1993) "Review of The Influence of Clay-Brine Interactions on The Geotechnical Properties of Ca-Montmorillonitic Clayey Soils from Western Canada," Canadian Geotechnical Journal. Vol. 30, PP 920-934.

4. Bell (1996) "Engineering Geology," Vol. 42, *PP* 223-237.
5. Bhattacharya J.K., A.V. Shekdar, and S.A. Gaikwad (2004) "Recyclability of Some Major Industrial Solid Wastes," Journal of Indian Association for Environmental Management. Vol. 31, No. 1, *PP* 71-76.
6. Brown, G. (1961) "X-Ray Identification and Crystal Structures of Clay Minerals," Mineralogical Soc, Clay Minerals Group, London, U.K.
7. Goldberg I, and A. Kelin (1952) "Some Effects of Treating Expansive Clays with Calcium Hydroxide," Symposium on Exchange phenomena In Soils, ASTM special publication, Vol.141.
8. Karthikayan, J (1989) "Removal of Colour In Dye Effluents Using Coagulation," PhD Thesis, IIT, Kanpur, India.
9. Katti R.K, Kulkarni R.K, and Radhakrishna (1962) "Research on Black Cotton Soil with and With Out Inorganic Chemicals," Indian Road Congress Bulletin, Vol.10, *PP* 01-79.
10. Mallikarjuna Rao K., and K. Chinnappa Reddy (1996) "Effect of Vat Dye Contamination on Properties of A Clayey Soil," Int. Conference on Environmental Planning and Management, Feb 24-26, V.R.C.E, Nagpur.
11. Mitchell J.K (1993) "Fundamentals of Soil Behavior," John Wiley and Sons, Inc, New York, 118.
12. Rajasekaran, G. and S. Narassimha Rao (1996) "Lime Stabilization Technique for The Improvement of Marine Clay," Soils and Foundations, Japan Vol. 37, *pp* 97 – 104.
13. Rajasekaran, G. (1993) "Physico-Chemical Behaviour of Lime Treated Marine Clays," Ph.D. thesis, Indian Institute of Technology, Madras, India.
14. Reddy Babu, G., K. Mallikarjuna Rao, and I.V. Ramana Reddy (2005) "Value Addition for Sludge Generated From Sand Beneficiation Treatment Plant," Nature Environment And Pollution Technology, Vol. 4(2), *pp* 203-206.
15. Sabry, M.A, Redd L.W, and J.V. Parcher (1981) "Mineralogy of Compacted Clay – Lime Mixtures," Journal of The Soil Science Society of America, Vol.45, *PP* 144 – 150.
16. Sinha, U.N., A.K. Sharma, S.N. Bhargava, A.K Minocha, and Pradeep Kumar (2003) "Effect of Seepage of Caustic Soda on Foundation and Remedial Measure in Alumina Plant," Vol.15.
17. IGC (2003) "Geotechnical Engineering for Infrastructural Development," Roorkee, India, Dec.18 -20.
18. Sridharan, A., T.S. Nagaraj, and P.V. Sivapulliah (1981) "Heaving of Soil Due to Acid Contamination," Proc.Tenth Int. Conf. Soil Mech. and Foundn. Engg Stockholm, *pp* 383 - 386.

19. Srimurali, M (2001) "Removal of Colour from Dye Wastes By Chemical Coagulation," ph.D. Thesis Submitted to Dept. of Civil Engg., S.V. University, India.
20. Bureau of Indian Standards (1995) "Standard Method for Determination of Liquid and Plastic Limit," New Delhi, IS 2720 Part 5.
21. Bureau of Indian Standards (1997) "Standard Method for Classification and Identification of Soils for General Engineering Purpose," New Delhi, IS1498.
22. Bureau of Indian Standards (1987) "Standard Method for Measurement of Swelling Pressure of soils," New Delhi, IS 2720 Part 41.
23. Bureau of Indian Standards (1997) "Standard Method for Determination of Consolidation Properties," New Delhi, IS 2720, Part 15.
24. Bureau of Indian Standards (1987) "Standard Method for Determination of soil pH Value", New Delhi, IS 2720 Part 26.
25. Tirumala Rao, V. (2004) "Effect of Spent Orange Dye Effluent on Properties of a Clayey soil," M. Tech. Dissertation, Dept of Civil Engg, S.V. University, Tirupati, India.
26. Zhang, H, M. Kamon, and T. Katsumi (2004) "Effect of Acid Buffering Capacity On The Long Term Mobility of A heavy Metals In Clay Liner, Soils and Foundations" Vol. 44, No. 6, *PP* 111 – 120.

