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XIII ICSMFE, 1994, New Delhi, India / XIII CIMSTF, 1994, New Delhi, Inde

LABORATORY STUDY OF SOIL-INDUSTRIAL WASTE WATER INTERACTION BEHAVIOUR

ETUDE EN LABORATOIRE DE L'INTERACTION SOL/EAU DE PECMARGE INDUSTRIELLE

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SYNOPSIS : This paper presents chemical and geotechnical analysis of waste water from four industries (paper mill, sugar mill, fertilizer plant and a power generation equipment manufacturing industry) and a typical alluvial soil (CL-ML type) from the planes of Northern India before and after their interaction. The problem of change in engineering behaviour of soils (Strength, deformation and seepage) on one hand and percolation of waste water to fresh water bodies due to modified seepage behaviour of soil on the other, has been observed and is a cause of concern to both geotechnical and environmental engineers. The study has indicated that even though the waste water meet the standards that have been set in by pollution control board, they significantly modify the permeability, strength parameters, and coefficient of consolidation of the soil in all the four interaction cases studied. There is a general deterioration in soil properties as far as geotechnical aspects are concerned in all the four cases. The study has indicated that it is largely the chemistry of waste water and of soil which is responsible for the modified engineering behaviour of soil.

INTRODUCTION

Industrial activity is necessary for the socio-economic progress of a country but at the same time it generates large amount of solid and liquid wastes. The wastes are source of ground contamination if not properly treated and disposed off. In developing countries, generally solid wastes are stored in the form of heap in tailing dams and liquid wastes are kept in shallow ponds or disposed off on ground with or without treatment. In recent years environmental pollution control boards have imposed restriction on disposal of wastes in rivers to prevent pollution because river water is most commonly used for human consumption. To escape from these restrictions, which require costly treatment of waste water there is a tendency to dispose off waste water on ground. It is being realised now that the indiscriminate disposal of waste water from industries may have a detrimental effect on engineering properties of soil which consequently leads to environmental problems. Even waste water being discharged from industries is not readily and willingly available for laboratory evaluation. In a recent newspaper report, Government of Uttar Pradesh, India has identified 109 industrial units of the state for legal action and this might be only a fraction of the whole thing. The present cause of concern is the likelyhood of waste water affecting the strength, deformation and seepage behaviour of soils on one hand and on the other, if this waste water gets connected to fresh water bodies (rivers, wells, ponds, lakes etc.) because of increased permeability of soils, the water available for human consumption would become a health hazard.

The studies carried out on soil-fluid (waste water/pollutants) are very few and most of the works have been carried out during last 15 years. The geotechnical aspects considered are effect of inorganic and organic permeants" water and waste water effect on soil behaviour, seepage behaviour of soil in acidic and alkaline environment, geotechnique of waste disposal and laboratory and field evaluation methods. Some of the important works on these aspects have been reported by Gordon and Forrest (1981), Hamilton, Daniel and Olson (1981), Olson and Daniel (1981), Alther et. al. (1985), Daniel, Anderson and Boynton (1985), Eklund (1985), Lentz et.al. (1985), Mitchell and Madson (1987), Kirov (1989), Landau and Enkeboll (1989) and recently by Pakhomov and Yegorv (1990). Case studies or laboratory evaluation of soil-waste water interaction from developing countries have not been reported in the literature so far" A detailed review of literature has indicated that understanding of the interaction effects would be useful in planning for beneficial use of waste water and control of detrimental effects. Thus there is a tremendous need of development and standardization of evaluation procedures and report of case studies.

The present study has been carried out on the interaction behaviour of a typical alluvial soil (CL-ML) found in the planes of Northern India and Waste water discharged after use from four industries (sugar mill, paper mill, fertilizer plant and a power generation equipment manufacturing industry) located in the state of Uttar Pradesh, India. To study the interaction effects, the soil has been tested with distill water first and then with the waste waters from the four industries separately. Coefficient of consolidation has been determined by performing consolidation test in a consolidometer and triaxial cell has been used as a permeameter (fig. 1) for determination of permeability and strength and deformation behaviour. The advantage of this has been that in this arrangement soil sample can be encased in a rubber membrane and saturated with the help of back pressure. The use of back pressure ensures saturation. The flexible membrane reduces problem of leakage between the specimen and the sides of permeameter.

The study reports engineering and chemical properties soil, chemical analysis of waste waters before and after it interacts with soil and changes in the engineering properties of soil.

PROPERTIES OF THE SOIL

The engineering and chemical properties of the soil are presented in table 1. Figure 2 shows particle size distribution curve. The results of X-ray diffraction analysis shown for the soil (fig. 3) indicate presence quartz, feldspar, kaolinite and mica minerals.

Table 1. Properties of the Soil

Property	Value
Liquid limit	31.88%
Plastic limit	21.59%
Plasticity Index	10.29%
Clay content	14.80%
Silt content	65.20%
Sand content	20.00%
Optimum moisture content	14.90%
Maximum dry density	1740 Kg/M^3
Permeability	1.01×10^{-4} m/s
Strength Parameters	
Soil remoulded at OMC & MDD	
and saturated ; c_u	0.0122 kPa
ϕ_u	0°
Coefficient of compression Cc	0.197
pH	8.10
Na^+ (a) Total	20 ppm
(b) Exchangeable	14 ppm
K^+ (a) Total	450 ppm
(b) Exchangeable	12 ppm
Ca^{++} (a) Total	150 ppm
(b) Exchangeable	30 ppm
Mg^{++} (a) Total	17 ppm
(b) Exchangeable	8 ppm
Fe^{++} (a) Total	1.4 ppm
(b) Exchangeable	0.7 ppm
Cu^{++} (a) Total	3.8 ppm
(b) Exchangeable	0.3 ppm

PROPERTIES OF THE INDUSTRIAL WASTEWATERS

The chemical properties of the waste waters from paper mill, sugar mill, fertilizer plant and power generation equipment manufacturing industry after they have been finally discharge for disposal is presented is table 2.

RESULTS

Table 3 and Table 4 present the modified properties of the four industrial waste waters (collected after they have leached through the soil in permeability test) and the changed engineering properties of the soil due to interaction with waste waters. Percentage variation in engineering properties of soil are also given.

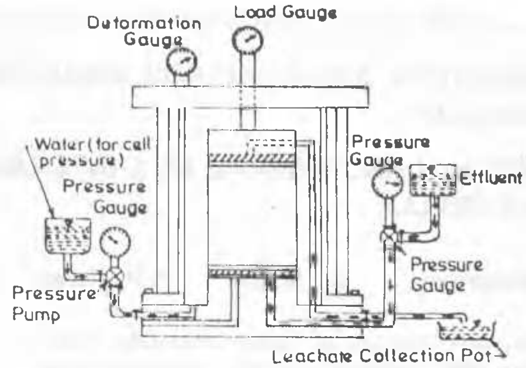

Fig.1. Schematic diagram of Triaxial cell for permeability test.

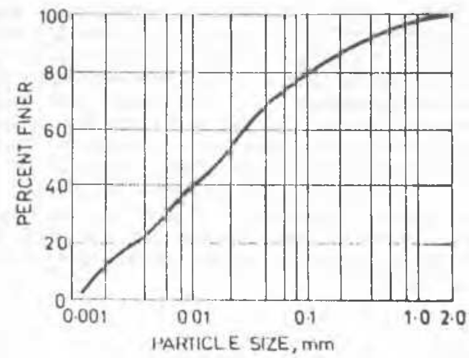

Fig.2. Particle size distribution curve.

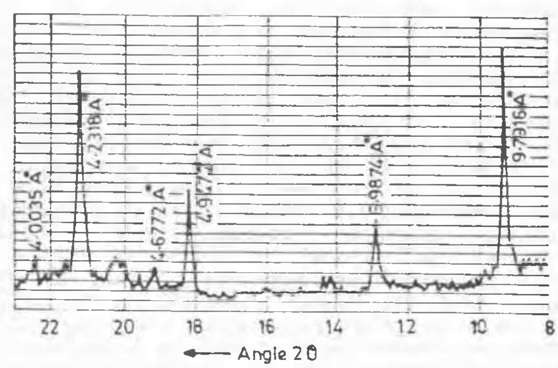

Fig.3. X-ray diffraction pattern of soil used.

DISCUSSION

Comparison of engineering properties of soil before and after its interaction with the four industrial waste waters (Table 1 and 4) shows that in general there has been an increase in liquid and plastic limits of the soil. The soil is most effected by paper mill waste water and least effected by sugar mill waste water. The maximum change in liquid limit is by 32.9% and minimum 7.9%. As compared to liquid limits, the change in plastic limits is significant. The maximum change being 30.5% and minimum 12.5%. It has been found that the maximum effect of soil-waste water interaction is being reflected in seepage behaviour of soil. The change (increase) in coefficient of permeability ranges from 129.7% to 252.4%. The maximum decrease in

Table 2 . Properties of Industrial Waste Water

Properties	Waste Water from Paper Mill	Sugar Mill	Fertlizer plant	Heavy Equipment
pH	7.10	7.75	7.65	8.60
Conductivity(umho)	4180	789	1308	635
Na^+ (ppm)	580.77	59.15	102	58.62
K^+ (ppm)	21.70	14.80	16	7.73
Ca^{++}(ppm)	22.15	46.3	49	38.7
Cl^- (ppm)	784.80	16.32	199	17.50
Total Hardness (ppm)	1292.60	214.75	402	257.08
Calcium Hardness(ppm)	1184.52	91.86	229	138.48
Magnesium Hardness(ppm)	108.17	122.89	173	118.60

Table 3. Properties of the four Industrial Waste Water after passing through Soil

Properties	Waste Water from Paper Mill	Sugar Mill	Fertlizer plant	Heavy Equipment
pH	7.25	7.40	7.20	7.65
Conductivity (umho)	4100	798	1316	642
Na^+(ppm)	305.15	38.40	82.00	39.41
K^+(ppm)	16.87	8.60	6.00	6.11
Ca^{++}(ppm)	18.06	34.51	28.08	26.21
Cl^-(ppm)	548.81	13.16	182.13	12.14
Total Hardness (ppm)	1251.56	270.56	680.00	311.55
Calcium Hardness (ppm)	1120.25	141.18	382.00	168.40
Magnesium Hardness (ppm)	131.31	128.48	298.00	143.15

Table 4. Modified Properties of the Soil after Interaction with Waste Water from the Four Industries

Properties	Waste Water from Paper Mill		Sugar Mill		Fertilizer Plant		Heavy Equipment	
	Value	Variation	Value	Variation	Value	Variation	Value	Variation
Liquid Limit	42.3%	32.9%	34.4%	7.9%	37.2%	16.7%	39.1%	22.6%
Plastic Limit	28.1%	30.5%	24.2%	12.5%	26.1%	20.9%	27.3%	26.6%
Plasticity Index	14.2%	37.9%	10.1%	1.8%	11.1%	7.9%	11.8%	15.3%
Coefficient of Permeability (m/s)	3.14×10^{-4}	210.8%	2.76×10^{-4}	173.0%	2.31×10^{-4}	129.7%	3.56×10^{-4}	252.4%
Strength Parameters from Soil Remoulded at OMC & MDD and Saturated with Waste Water								
(a) Cohesion(kPa)	0.0071	41.8%	0.0101	17.2%	0.0094	23.1%	0.0069	43.4%
(b) Angle Ø	0°		0°		0°		0°	
Coefficient of Compression Cc	0.266	35.0°	0.201	2.0%	0.245	24.4%	0.232	17.7%

shear strength is of the order of 43.4%. It is marginal in case of sugar mill waste water. There has been an increas in coefficient of compressibility in all the cases. But in case of sugar mill waste water the change is almost negligible, where as in other cases it is moderate. The maximum increase being 35.0% in case of paper mill waste water. Thus in the four cases of interaction that have been studied almost similar type of deterioration in soil properties is observed. The decrease in shear strength is indicative of decrease in bearing capacity of soil. The increase in coefficient of compression reflects the increasd proneness of soil to higher settlements. The comparative large increase in coefficient of permeability is a matter of concern. It indicates the possibility of increased seepage of waste water and possibility of it joining fresh water bodies. A future environmental and ecological problem can be expected.

In the present study, all the four industrial waste waters are alkaline in nature. The chemical nature of the waste waters are reflected from table 2 and 3. The effect of these waste waters on soil is possibly to increase dispersion of soil particles and thereby cause an overall deterioration in soil properties. (It may be conversely surmised that in case of waste waters acidic in nature, the effect of interaction with present soil might be of stabilizing it). It is observed that various parameters e.g. pH, conductivity, cation content, anion content and hardness have been modified because of this interaction. Some of the chemicals have been absorbd by the soil from waste water and some chemicals must have leached out to waste water during interaction. In the present study, in all the four cases, cation content of the waste waters have decreased and hardness of the waste waters have increased after interaction.

An overall problem of future reclamation of disposal site and adjacent areas is indicated. A visit to the four sites of disposal has indicated that the waste water from paper industry is likely to cause maximum harm (Presene of large amount of chlorine ion is important in this case). A survey of the area and discussions with the resident, have also indicated that fish life in the stream has almost become extinct. The water from stream and near by well has became very hard and it is not good for drinking purposes. The effect due to sugar mill waste water is at present moderat only. But waste water from fertilizer plant and heavy equipment manufacturing unit is also significant. In case of areas effected by fertilizer plant waste water, villagers have reported change in colour and taste of water in wells located near the lake where ultimately this waste water is disposed off.

The present study has been a short term study of Soil behaviour in industrial waste water environment. The long term effects are expected to be more important and revealing. Further, an inference from present study may be that depending upon the type of soil and waste water, a combination for the beneficial use of waste water (for improving strength, reducing volume changes and permeability) is also possible.

CONCLUSIONS

Following conclusions have been drawn from the present study.

The soil as well as all the four waste waters are alkaline in nature.

There has been increase in consistency limits and coefficient of compressibility in all the four cases, the maximum being in case of interaction with paper mill waste water. But sugar mill waste water has almost negligible effect on coefficient of compressibility.

There has been decrease in shear strength of soils, higher decrease being in case of interaction with waste water from paper mill and power generation equipment manufacturing industry.

The most alarming aspect of soil-waste water interaction is the increase in coefficient of permeability. The increase is maximum in case of power generation equipment manufacturing industry.

The Total hardness of paper mill waste water is very high and in general there is an increase in hardness of waste waster after interaction. Thus available water would slowly become unifit for human consumption and rural population would be espcially effected because they use water directly from wells, ponds and other water bodies.

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