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Evaluation of suitability of oil well drill cuttings for road making

A K Misra*, Renu Mathur, Pankaj Goel and Manoj Kumar Singh
Central Road Research Institute (CRRI), New Delhi 110 025, India

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This study presents that oil drill cuttings waste can be a very good costruction material for sub-grade preparation of roads without causing any toxic effects on natural soil/ ground water etc. Use of drill cuttings for sub-grade construction will reduce pavement thickness and thus cost of construction will also be less.

Keywords: Oil drill cuttings, Road making, Sub-grade construction

Introduction

Process of drilling oil and gas wells generates large volumes of drill cuttings and spent muds. These drill cuttings contain hydrocarbons, salts, metals, soaps and other agents that have been added to drilling fluid to assist in drilling and hydrocarbon recovery processes or that has become mixed with drilling fluid from the formation. This study evaluates fesability of using drill cuttings in road making and also to estimate heavy/ toxic metals in cutting lechates.

Experimental Section

Sample Collection

Drill cutting samples (5) from various depths were collected from an oil well at Dahej, Gujarat field. At site, on visual inspection, drill cuttings appeared to be aggregates of different sizes coated with mud. But when dried, aggregates crumbled under light finger pressure and resembled soil particles, therefore, characterization of drill cuttings was done similar to soils. Five bags of each sample were thoroughly mixed to prepare a homogenous mix as per IS: 2720, Part-1[1]. A sixth sample was also prepared by mixing all five samples in equal quantities. Samples were designated from A to F.

Laboratory Studies

Grain size analysis[2] of drill cuttings was carried out by different sieve sizes (Fig. 1). Liquid limit (LL) test[3] and plastic limit (PL) test[3] were performed on prepared specimens. Based on grain-size analysis and plasticity index, drill cuttings were classified as per unified soil classification system. Proctor test[4], California Bearing ratio (CBR) test[5] and unconfined compressive strength (UCS) test[6] were also performed. OMC, MDD, CBR, UCS etc. were found out (Table 1).

Leaching Studies

For this study, cylindrical samples (diam, 5 cm; ht, 10 cm at OMC & MDD) were prepared and soaked in distilled water for 30 days. After soaking, water was filtered using Whatman - 40 filter paper. Clear solution was digested on a water bath to evaporate water. Dry samples were used to determine heavy metals present in drill cuttings as soluble salts.

Estimation of Heavy/Toxic Metals

Samples were fused with lithium tetra borate in platinum crucible at 1000°C. Fused mass was extracted with dilute nitric acid. Solution was filtered using Whatman 40 filter paper in a volumetric flask. After washing, volume was made up to 500 ml. Solution was then analysed using an inductively coupled Plasma Spectrometer (Vista MPX, Varian, USA) simultaneous system, for all elements (Table 2). A Flame Atomic Absorption spectrometer (FAAS) (Analytik Jena, Vario–6) with a vapor generation accessory (AAS–HG) was used for analysis.

For determination of Hg, sample (0.5 g) was taken in cleaned PTFE vessels. Further, sub boiled nitric acid (15 ml), hydrogen peroxide (5 ml) and DI water (5 ml) were added to vessels, which were closed with airtight lids and kept for overnight at room temperature (RT).

*Author for correspondence
E-mail: akmishra.crri@nic.in

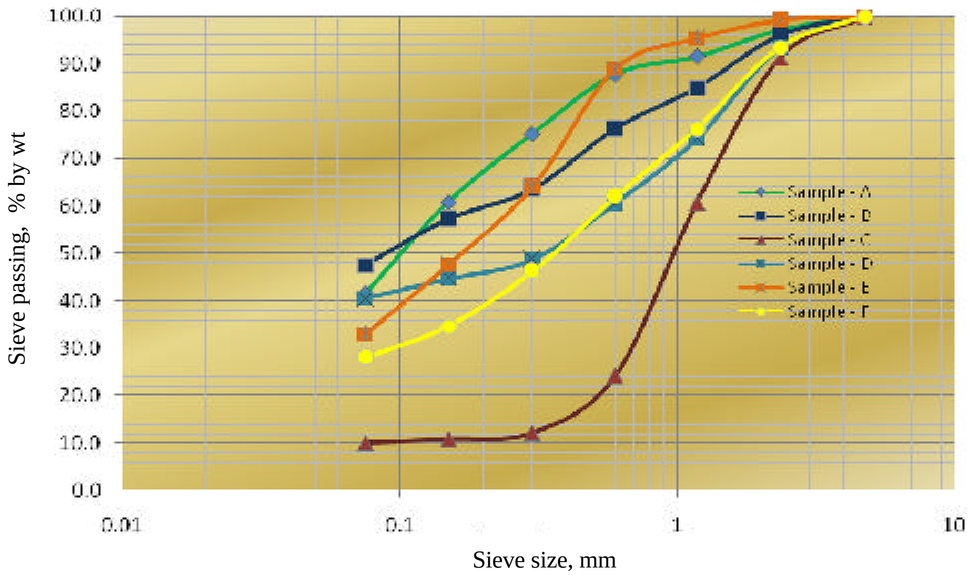

Fig. 1—Grain size distribution of drill cutting specimens

Table 1—Engineering properties of drill cuttings

Engineering properties	Drill cutting specimens					
	A	B	C	D	E	F
Liquid limit (LL), %	29.1	39.4	40.0	40.4	34.8	33.4
Plastic limit (PL), %	17.0	22.6	26.2	26.2	19.0	17.6
Plasticity Index (PI), %	12.1	16.8	13.8	14.2	16.8	15.8
Maximum dry density (MDD), g/cc	1.97	1.86	1.92	1.88	1.98	2.10
Optimum moisture content (OMC), %	13.65	15.74	13.36	14.93	13.90	11.10
California bearing ratio (CBR), %	16.0	12.7	30.0	11.7	25.7	28.4
Moisture absorption, %	4.9	4.4	1.7	6.6	6.0	2.0
Unconfined compressive strength (UCS), kg/cm^2	32.50	47.32	35.00	40.50	35.17	48.67

Then, PTFE beakers were digested on hot plate after adding 4-5 drops of sulfuric acid at 160-180°C by covering them with a Teflon lid for 2-3 h to obtain a concentrated solution. Samples with residue were heated twice on hot plate with 10 ml and then with 5 ml of concentrated hydrochloric acid (HCl) to ensure a complete removal of nitric acid. Finally, solution was boiled with water, HCl (1:1) mixture (15 ml). After digestion, whole content was centrifuged at 5000 round per min for 3 min. Whole precipitates were washed several times with hot water to ensure complete transfer of digested sample from vessel. Final volume was adjusted to 50 ml by de-ionized water. In solution, Hg was determined by hydride generator after reducing in presence of sodium boro-hydride (3%), sodium hydroxide (1.5%) and HCl (1%) using electro–thermal heating at RT. Mean absorbance values were taken of three readings of two replicates (3 each). Procedural blanks for reference without sample was also run to check blank levels for Hg and blank correction applied wherever required. Standard addition (of known quantity–100 µg/kg, 5 ml of 1000 µg/kg in 50 ml volumetric flask) procedure was also applied for Hg in the beginning and processed same as samples to check losses during preparation process and to check reliability of wet digestion (Table 2).

Results and Discussion

Particle size analysis of specimens (A-F) show that while whole of drill cuttings pass through 4.75 mm sieve size, more than 50% fraction of drill cuttings are coarser than 75 µ size. Plasticity test conducted on fraction passing 425 µ sieve size of all drill cuttings showed as follows: LL, < 50%; and PL, > 12%. Based on Unified Soil Classification System, drill cuttings were classified

Table 2—Heavy/ toxic metals in leachates

S No.	Metals	Heavy/toxic metals, mg/kg				
		A	B	C	D	E
1	Barium	90	90	190	80	180
2	Chromium(III & VI)	40	20	70	30	20
3	Lead	0	0	0	0	0
4	Nickel	0	0	0	0	0
5	Copper	160	70	90	100	40
6	Cobalt	0	0	0	0	0
7	Cadmium	0	0	0	0	0
8	Zinc	0	0	40	0	0
9	Molybdenum	60	0	0	0	0
10	Strontium	0	140	170	180	80
11	Arsenic	0	0	0	0	0
12	Selenium	0	0	0	0	0
13	Manganese	10	10	10	10	10
14	Mercury	0	10	0	0	0

as sandy soils (100% passing through 4.75 mm mesh) associated with clay of low plasticity (LL, < 50 & PI, 12-17%), viz. SC. Results of proctor compaction test revealed high density of drill cuttings. CBR test indicates that cuttings have high load bearing capacity. UCS is also very good. Sample prepared by mixing all five samples procured from site shows best gradation, covering maximum range of particle size (well graded) and is most suitable to achieve high density and strength (Table 1). Further from practical point of view (as it is difficult to stock wastes from various depths separately), it will be more convenient to use this mix in construction of roads. Heavy metals leached out from drill cuttings are within permissible limits as given in Schedule II of hazardous waste[7].

Economy

Use of oil well drill cuttings in road construction will not only utilize a waste material but will also save soil. Since CBR of drill cuttings is high (design CBR-10%) as compared to local soil (design CBR-2%), use of drill cuttings will reduce total pavement thickness considerably. Pavement thicknesses, as per IRC-37[8], have been worked out for *in-situ* soil and drill cuttings. Data used for pavement design of two lane carriageway is as follows: initial traffic, 1000 commercial vehicle per day; vehicle damage factor, 3.5; and design life, 10 years. Thickness of pavement for local soil and drill cuttings, on 600 mm sub-grade, correspond to 850 and 540 mm respectively, comprising, 140 mm bituminous surface, 250 mm base & 460 mm sub-base for local soil and 90 mm bituminous surface, 250 mm base & 200 mm sub-base. Cost for these two thicknesses are Rs 1,81,83,256.00 and Rs 1,08, 37,076. Thus a saving of 40% can be achieved by using drill cuttings in sub-grade preparation.

Conclusions

Oil well drill cuttings are having all desired engineering characteristics to be exploited as a potential material for preparation of stable and strong sub-grade for roads. Amount of heavy/toxic metals is negligible and therefore can be safely used in road construction.

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