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The Gravel Packing Chacteristics of Ethiope River Sediments, Southern Nigeria

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Abstract: Sand production in water, oil and gas wells is usually controlled by gravel packing techniques worldwide. Consideration in the gravel pack design requires that the particle size is five or six times the formation sand depending on the formation sand median diameter. Sieve analysis result shows that the grain sizes of sand and gravel of the Ethiope River sediments fall within the size range (0.378-12.0mm) recommended for a gravel pack by the American Petroleum Institute. Acid solubility test on the gravel and sand gives desirable results as the maximum solubility of 1.0% required for gavel pack is not exceeded. The sphericity and roundness of the particle grains range from 0.70-0.68 and 0.70-0.67 respectively, which is within the range ($\geq$ 0.6) allowed for gravel pack. The presence of the objectionably high content of silt and clay in some of the samples particularly those collected near the Ethiope River source area (e.g. UM1-UM10) however reduces the pack efficiency and formation permeability as the "fines and mud" tend to clog the screen slots (openings). A possible solution to this problem will entail some systematic process of flushing out "fines and mud" from the deposit prior usage.

Key words: Abraka · Ethiope River · Gravel packing · Obiaruku · Umutu · Sieve analysis · Southern Nigeria

INTRODUCTION

The study area encompasses Umiaja-Umutu, Obinomba, Obiaruku and Abraka Towns in the Ethiope River Catchment, Niger Delta Sedimentary Basin of Nigeria (Fig. 1). The Ethiope River flows northwesterly from its source area (Umiaja-Umutu) through Abraka to Sapele before joining the Benin River, which empties into the Atlantic Ocean. The banks and beds of the Ethiope River and its tributaries in the study areas are endowed with vast gravel and sands of variable sizes. Various studies have been carried out by workers on gravel pack and its efficiency in sand control in oil and water wells in different parts of the World [1-13]. However, in Nigeria with particular reference to the Niger Delta, there is little or no information available on the enormous gravel and sand deposits and their potential for gravel pack. Consequently, the problem of sourcing suitable gravel packing materials continues to plague the water and petroleum industries. In this study, a geological study of the sand and gravel deposits in the Ethiope River Catchment areas is undertaken to evaluate its usability for gravel pack in the industries.

Geology: The study area is part of the southwestern segment of the Niger Delta Sedimentary basin of Nigeria (Fig. 1). The sediment is composed of white to local brown, poorly sorted, sub-angular to well rounded continental sands and gravels of the Benin Formation [14]. The Benin Formation which unconformably overlies the Agbada and Akata is Pleistocene-Recent and is approximately 2000m thick. The Agbada (Miocene-Pliocene) consist of alternating sand and shales of over 4000m thick while the Akata Shale (Oligocene-Miocene) is up to 6000m thick [15, 16].

The sedimentation in the Niger Delta Basin continues at the present times as the Niger and Benue River Systems bring large volume of sediments to the sea each year. River sands are deposited consequently in numerous distributary river channels on the Delta top and are redistributed by waters and Longshore currents to form beach ridges and sand bars. Mud is deposited in the lower energy and deeper offshore waters over the continental slope; the sands and mud are deposited in deep sea fan from turbidity currents flowing down the slope, often in submarine canyons and these forms the continental rise [17].

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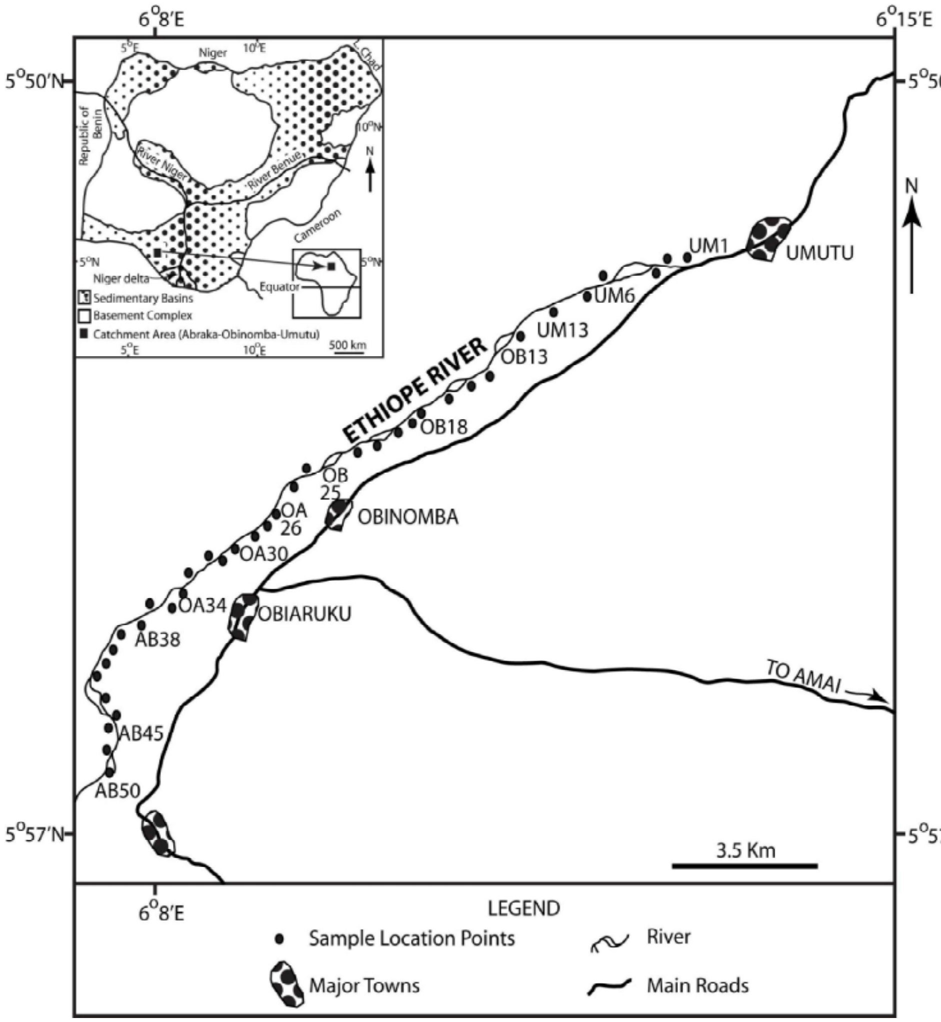

Fig. 1: Map of Ethiope River catchment area showing sample location points. Insets: Geologic Map of Nigeria (after Kogbe, 1976) and map of Africa showing location of catchment area

MATERIALS AND METHODS

Fifty (50) samples were randomly collected both from the river beds and from banks where the sand and gravel are exposed throughout the study areas (Fig. 1). The following Laboratory tests conducted on the samples conform to the standard recommended for appraising gravel packs [1, 3, 4, 6, 8, 10, 18]:

***Sieve Analysis* of Particle Size Distribution:** Dry weights were recorded for particle grains from Sieves and result plotted as a percent (%) weight retained versus particle sizes (mm) (Fig. 2).

***Solubility Test*:** This is to unravel the amount of undesirable components (i.e. carbonates, feldspars, iron oxides, etc.) present in deposits. The procedure adopted for this test entailed weighing 5.0 gram specimen from the different samples, dried in an oven at 105°C to a constant weight and cooled in a desiccator. A 100ml of 12-13HCL-HF acid was added to the specimens at room temperature (22±3°C) and observed for 60 minutes. The mixture was filtered taking precaution to ensure all particles of sand and gravel were transferred into the filter. The residue of sand and gravel particle grains was washed in the filtering apparatus for three times with 200ml of distilled water. The filter with retained fraction was dried at 105°C for 60 minutes and allowed to cool before weighing. The solubility of the sand/gravel was computed as shown below with results presented in Table 1.

$$S = (Wa+Wb-WC)/Wa*100$$

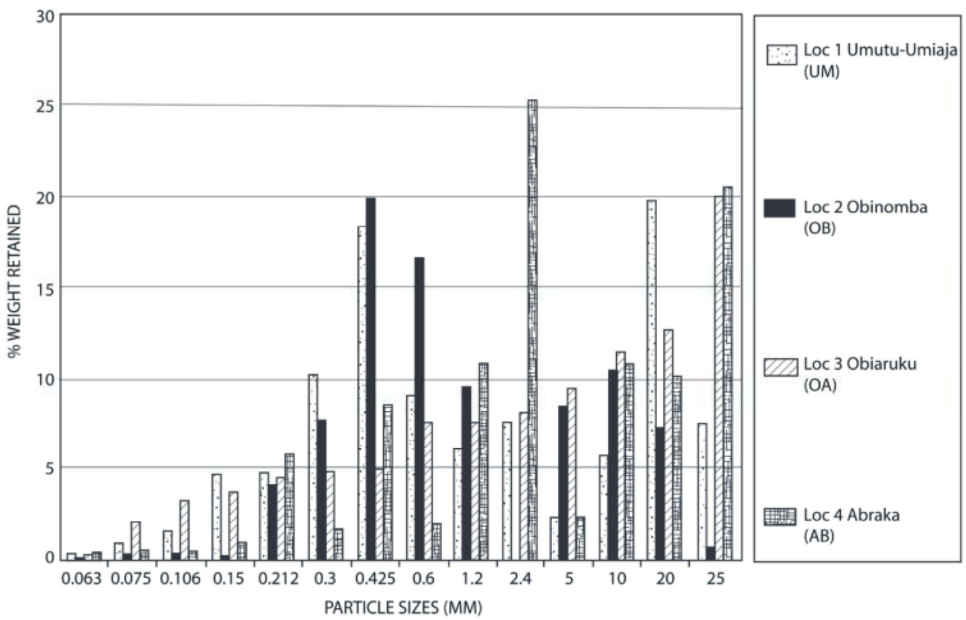

Fig. 2: Chart of weight retained (%) versus particle sizes (mm)

Table 1: Solubility Test Results

Sample Number.	Solubility (%)	Sample Number.	Solubility (%)
UM1	0.97	OA26	0.70
UM2	0.94	OA27	0.66
UM3	0.96	OA28	0.66
UM4	0.96	OA29	0.67
UM5	0.97	OA30	0.68
UM6	0.94	OA31	0.70
UM7	0.95	OA32	0.67
UM8	0.90	OA33	0.67
UM9	0.96	OA34	0.66
UM10	0.95	OA35	0.68
UM11	0.97	OA36	0.95
UM12	0.96	OA37	0.94
UM13	0.94	AB38	0.90
OB14	0.54	AB39	0.95
OB15	0.53	AB40	0.94
OB16	0.54	AB41	0.95
OB17	0.55	AB42	0.95
OB18	0.53	AB43	0.94
OB19	0.50	AB44	0.92
OB20	0.55	AB45	0.94
OB21	0.51	AB46	0.94
OB22	0.55	AB47	0.95
OB23	0.54	AB48	0.94
OB24	0.68	AB49	0.94
OB25	0.68	AB50	0.95

where,

S = Solubility of sand/gravel expressed as weight percent

Wa = Weight of sand/gravel

Wb = Weight of filter

Wc = Weight of filter + sand/gravel after washing

***Shape Test*:** This is to determine the roundness and sphericity of the particle grains selected from the samples in the different locations. To find out how close gravel/sand particle approaches a sphere and the relative sharpness of grain corners or of grain curvature, the chart developed for use in visual estimation of sphericity and roundness [19] was adopted. To enable this test, 20.0 grams of particle grains were randomly picked for examination with the aid of a 10-20 power microscope and average sphericity and roundness is obtained for the samples (Table 2).

***Silt and Clay Test*:** Specimens of different samples were weighed and dried in an oven at 105°C for 24 hours and washed through a 63μm British Standard (BS) Test Sieve to remove silt and clay components. Washing was discontinued when water passing through the sieve becomes clear. The specimen was then reweighed and the difference in the initial and final weight gave the silt and clay proportions presented in Table 3.

RESULTS AND DISCUSSION

The result of the sieve analysis shows that the deposits in the Ethiope River catchment areas are characterized by particle sizes that range from fine sand to coarse gravel with the quantity of gravel (passing 2.24mm) ranging between 42.8-23.6% while the quantity of gravel (passing 0.063-2.0mm) falls between 76.3-55.7%. It is evidenced from Figure 2 that the quantity of gravel

Table 2: Result of Shape Test Using Krumbein and Sloss Chart (1963)

Sample Number	UM 1	UM 2	UM 3	UM 4	UM 5	UM 6	UM 7	UM 8	UM 9	UM 10	UM 11	UM 12	UM 13	GRAND Average
Average Roundness	0.5	0.5	0.9	0.7	0.5	0.5	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.70
Average Sphericity	0.9	0.9	0.5	0.7	0.5	0.5	0.9	0.7	0.5	0.9	0.5	0.7	0.9	0.68
Sample Number	OB 14	OB 15	OB 16	OB 17	OB 18	OB 19	OB 20	OB 21	OB 22	OB 23	OB 24	OB 25		
Average Roundness	0.3	0.5	0.5	0.9	0.7	0.9	0.7	0.7	0.9	0.9	0.5	0.7		0.68
Average Sphericity	0.5	0.7	0.5	0.9	0.5	0.9	0.7	0.7	0.7	0.9	0.9	0.5		0.70
Sample Number	OA 26	OA 27	OA 28	OA 29	OA 30	OA 31	OA 32	OA 33	OA 34	OA 35	OA 36	OA 37		
Average Roundness	0.5	0.9	0.7	0.5	0.5	0.7	0.5	0.7	0.7	0.9	0.9	0.5		0.67
Average Sphericity	0.7	0.9	0.5	0.3	0.9	0.7	0.5	0.9	0.5	0.7	0.7	0.9		0.68
Sample Number	AB 38	AB 39	AB 40	AB 41	AB 42	AB 43	AB 44	AB 45	AB 46	AB 47	AB 48	AB 49	AB 50	
Average Roundness	0.9	0.7	0.9	0.7	0.5	0.7	0.9	0.5	0.7	0.5	0.5	0.7	0.9	0.70
Average Sphericity	0.5	0.7	0.9	0.5	0.9	0.7	0.7	0.5	0.9	0.5	0.7	0.9	0.7	0.70

Table 3: Silt and Clay Proportions

Sample Number	Silt/clay Percent	Sample Number	Silt/clay Percent
UM1	1.55	OA26	0.18
UM2	1.56	OA27	0.17
UM3	1.55	OA28	0.18
UM4	1.54	OA29	0.16
UM5	1.50	OA30	0.18
UM6	1.54	OA31	0.18
UM7	1.55	OA32	0.16
UM8	1.56	OA33	0.10
UM9	1.50	OA34	0.18
UM10	1.58	OA35	0.17
UM11	1.58	OA36	0.16
UM12	1.55	OA37	0.12
UM13	1.58	AB38	0.53
OB14	4.26	AB39	0.51
OB15	4.25	AB40	0.53
OB16	4.26	AB41	0.53
OB17	4.22	AB42	0.50
OB18	4.21	AB43	0.51
OB19	4.00	AB44	0.49
OB20	4.26	AB45	0.50
OB21	4.25	AB46	0.41
OB22	4.20	AB47	0.50
OB23	4.21	AB48	0.54
OB24	4.00	AB49	0.53
OB25	4.26	AB50	0.53

Table 4: American Petroluem Institute (API) General Specifications (1970)

Test	Property	Specification
Sieve Analysis	D(50) (μm)	Non specified
	Deviation from spec. (%)	Non specified
	Percentage fines	Max. 2
	Percentage oversize	Non specified
	Percentage between sieves	Min. 96
Shape	Roundness	0.6
	Sphericity	0.6
	Multicrystalline grains (%)	Non specified
Solubility	In HCl (% sand weight)	Non specified
	In mud acid (% sand weight)	Max. 1
Silt and Clay	% Volume	Max. 1

decreases as the quantity of sand increases away from the Ethiope River source area suggesting that the size of the particle-load have control on the distance of transport of stream load from source. In accordance with the gravel sizing criterion recommended by [6], the gravel pack individual particle should be 5-6 times as large as the formation sand and this corresponds commonly to a size fraction of between 0.378-12.0mm i.e. from medium sand to medium gravel particle size range depending on the formation sand median diameter. The Size-distribution chart (Fig. 2) obtained for the samples depicts the deposits as satisfying this standard because the medium sand (0.380mm) to coarse gravel (20.0mm) of the area falls dominantly within the range of the recommended size fraction (i.e. 0.378mm-12.0mm).

Solubility percentage (0.50-0.97%) obtained for the samples (Table 1) portrays the sands and gravel to be of low solubility with more than 99% quartz which suggests the deposits to be of high quality. The use of high quality gravel is an important factor for placing an unimpaired gravel pack [4]. The almost exclusive quartz component of the deposits would make the packs to be resistant to crushing and attacks by acids (mineralizing fluids). Additionally, it will prevent excessive "fines" generation under loading and pumping conditions. Furthermore, the phenomenon of multi-crystallinity that may contribute to fines generation when gravel is subjected to load is not reminiscent of the sand and gravels from the study areas. The analysis of the solubility results presented in Table 1 suggests the sand and gravels did not exceed the maximum solubility limit of 1.0% allowable for gravel pack design (Table 4).

The shape test of representative grains for the samples reveals the average roundness and sphericity to vary between 0.67 and 0.70 and 0.68 and 0.70 respectively (Table 2). As shown in the API gravel pack specifications (Table 4), this is a favourable shape test result as virtually all the particle grains have roundness and sphericity greater than the allowable minimum of 0.6.

As regards the silt and clay test on the samples (Table 3), the percentage obtained are 1.50-1.58 for samples (UM1-UM13) of the Ethiope River source area, 4.00-4.26 in the case of Obinomba sand and gravels (OB14-OB25); 0.10-0.18 for samples from Obiaruku (i.e. OA26-OA37), whereas the sand and gravel deposits in Abraka area (i.e. AB38-AB50) gives a silt/clay percent of 0.41-0.54. With the exception of the deposits in Abraka and Obiaruku, the others exceeded the upper limit of 1.0% allowable for effective gravel packing (Table 4). An explanation for this is that samples UM1-UM13 and OB14-OB25 are located within and near the source area respectively while samples OA26-OA37 and AB38-AB50 are located further upstream the Ethiope River (Fig. 1). The unexpectedly high silt/clay content of samples from Obinomba may be attributed to the more or less stagnant water bodies in which samples were collected as opposed to those from the source area collected from within flowing water channels that resulted in the removal or reduction in the mud and fines inherent in the former.

CONCLUSION

The gravel pack appraisal of deposits of gravels and sand in the Ethiope River catchment areas of Umuaja-Umutu, Obinomba, Obiaruku and Abraka was conducted using a total of 50 samples randomly collected from the river bed. The results of the various tests on samples of the deposits are favourable with respect to the specifications recommended for gravel pack design by various workers. As a result of these findings, the gravels and sand will be suitable for gravel packing in gas, oil and water wells. The only objection to its effective use is the unavoidably high contents of clay and silt in samples from the Ethiope river source area (i.e. UM1-UM12) and Obinomba (OB13-OB25). It has been reported that excessive fines when present in the gravel pack poses a problem of reducing pack and formation permeability [1, 4, 6, 9, 11]. This problem could be avoided when caution is taken to involve a systematic method of using water as the flushing medium that will ensure the removal of fines from the deposit prior usage. However when situations allow the practice of the mineral high grading technique, resource exploitation could be concentrated in areas (e.g. Obiaruku and Abraka) where the silt and clay content is below the tolerable limit of 1.0%.

A point worthy of note is that before proceeding with gravel pack design, it is invaluable to check the quality of samples of the formation sand for the interval of interest. This is because if samples are poorly sorted (with uniformity coefficient, C = D60/D10 > 5), there is a high risk that the gravel pack will not effectively control formation sand and will become impaired due to fine sand invading the pack [2, 11]. Whenever a situation of this sort is encountered, a plausible remedy will involve carrying out gravel sizing according to Saucier's rule [6] which requires that a range of size 5-6 times the formation particle diameter at 50 percentile (median) point of the sieve analysis be used.

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