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SUITABILITY OF LOCALLY SOURCED GRANULAR AGGREGATES FROM SOUTHWESTERN NIGERIA AS FILTERS FOR EROSION CONTROL IN EMBANKMENT DAMS

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ABSTRACT: *Filter with simple but effective job is one of the principal parts in an embankment dam which is able to immune the dam against erosion, prevent water escape and seal unfavorable cracks that may occur through the impermeable core. Geotechnical properties of granular materials (filters) from two States in the Southwestern Nigeria were presented in this paper, using locally and commercially sourced aggregates. Nine granular soil samples were collected: peat and sharp sands from two borrow pits; gutter and river sands with gravel from Ogbomoso, Oyo State; quarry dust and granite from Ministry of Transport Osogbo, Osun State. Samples were subjected to the following laboratory tests: Particle size analysis, Atterberg limit, Compaction, Specific Gravity, Constant Head Permeability. Results of the particle size analysis passing sieve No. 200 for peat, sharp, gutter, and river sands, with gravel, quarry dust and granite were 2.94%, 1.12%, 0.81%, 1.35%, 3.13%, 0.68%, 0.58%, 5.93% and 0.32% respectively while those passing through sieve No. 4 are 97.92%, 89.91%, 97.22%, 95.90%, 26.76%, 88.05%, 96.50%, 97.93% and 24.71% respectively. The plasticity Index were 5.13%, 6.94%, 8.17%, 6.11%, 8.37%, 0.59%, 2.47%, 2.48% and 10.76% respectively. Optimum moisture content and maximum dry density were (5.11% ;1830 Kg/m^3) , (6.57% ;1960 Kg/m^3) , (12.36% ;1940 Kg/m^3) , (8.57% ;1930 Kg/m^3) , (8.73% ;2080 Kg/m^3) , (11.86% ;2150 Kg/m^3) , (7.73% ;1820 Kg/m^3) , (6.10% ;1840 Kg/m^3) and (6.29% ;1720 Kg/m^3) respectively. Specific gravities of the samples were 2.73, 2.70, 2.75, 2.80, 3.02, 2.84, 2.85, 2.82 and 3.98 respectively. Permeability coefficients were 3.54 × 10^{-5}cm/s, 3.14 × 10^{-5}cm/s, 3.59 × 10^{-5}cm/s, 3.64 × 10^{-5}cm/s, 2.59 × 10^{-5}cm/s, 3.09 × 10^{-5}cm/s, 2.87 × 10^{-5}cm/s, 2.78 × 10^{-5}cm/s respectively. The locally sourced materials are adequate and suitable to serve as filter materials, with relatively low cost compared to commercially sourced aggregates.*

KEYWORDS: Erosion, Filters, Geotechnical Properties, Granular Material, Locally Sourced

INTRODUCTION

Despite the large uses that dams offered, the destructive effect of water on dam cannot be overemphasized. One of the very common failures in earth dam is seepage and piping. Seepage is a term used to describe the continuous passage of water from the upstream face of the dam to the downstream face through the pores and voids of soils while piping is the movement or percolation of water carrying soil particles through the earth dams. The use of filter is hence one of the effective method of checking seepage and piping in earth dams. A filter is a medium used to sieve soil particles but allow the flow of water through it without washing away of dam materials.

The distribution of voids or pores in the filter is the main property of filter functioning. This characteristic affects the retention and permeability criteria, several parameters directly or indirectly influence the performance of filter (Sherard and Dunnigan, 1989). Yasrobi et.al. (2004, 2008) listed the effective parameter in filter designing among which are: Gradation Curve, Permeability, Filter Thickness, Relative density etc. The most important kind of filter in an embankment dams are critical filters downstream the dam. The filter should not permit almost any erosion and has to conduct the pore water pressure out of the dam. Today geo - synthetic filters can be produced in exact void sizes, the changes in physical and chemical properties of geo - synthetics during the time and also the non-compatibility with soil made them unsafe alternative at least for uses in large dams (ICOLD,1994). Sand- Gravel Filter consists of a layer or blanket of well graded sand gravel aggregate placed over the embankment or river bank before the placement of rip rap whereas the synthetic filter clothes are synthetic clothes that are placed on polyvinyl chloride PVC pipe. The size of gravel in the filter blanket should be from 3/16 inches (5mm) to an upper limit depending on the gradation of rip-rap with maximum sizes of approximately 3-3 ½ inches (90mm).

MATERIALS AND METHODS

Seven locally sourced aggregate samples were collected from Ogbomoso, Oyo State. They were peat and sharp sands from Ago borrow pit, peat and sharp sands from Ile Ewe borrow pit, gravel, gutter and river sands. The other two commercially sourced aggregates samples: quarry dust (stone dust) and granite (½ inches size) were collected from Ministry of Transport and Geotechnical Laboratory Osogbo, Osun State. The nine samples were taken to the laboratory where six laboratory tests relating to filter properties were performed on them. The Laboratory tests were: Particle size analysis, Atterberg limits,West Africa Standard Compaction, Specific gravity and Constant Head Permeability, according to (BS 1377: 1975, and Part 2:1990).

RESULTS AND DISCUSSIONS

Summary of the laboratory results was presented in Table 1. Figures 1-9 showed the particle size distribution graphs. Below are the discussions of the results:The results of the particle size analysis for % passing #200 were 2.94%, 1.12%, 0.81%, 1.35%, 3.13%, 0.68%, 0.58%, 5.93% and 0.32% respectively, while 97.92%, 89.91%, 97.22%, 95.90%, 26.76%, 88.05%, 96.50%, 97.93% and 24.71% respectively passing through sieve #4. Only the gravel sample from Ogbomoso and granite from Osogbo fell out of the USDA, SCS (1986) standard of 55-80% passing sieve #4; and not more than 5% passing #200 sieve. All of the samples except, stone dust from Osogbo defaulted. Fine sand with D_{15} between 0.1 and 0.3mm provides an adequate filter for dispersive soils. D_{15} greater than 0.1mm ensures a cohesionless fine, unless clay fines or carbonate cement is present. With these recommendations, the locally sourced granular filter materials met the retention (piping or stability) criterion. The requirement that the D_{15} must not be finer than 0.1mm was met by all the granular filter materials. It is recommended that sand or sand-gravel with top size of 12.7-19.0mm (1/2 -3/4 inch) be used as drain.

The Plasticity Index values were 5.73%, 6.94%, 8.17%, 6.11%, 8.37%, 0.59%, 2.47%, 2.48% and 10.76% respectively while the shrinkage limit are all 0 except for gravel that has 2.89%. Gravel has the highest Plastic Index and shrinkage value which indicates that its contains a largest percent of fine materials thus it required a large amount of moisture content to take from solid state to liquid state and a small amount of moisture to be removed to take from liquid to plastic stage. The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) were, (5.11% ;1830 Kg/m^3) , (6.57% ;1960 Kg/m^3) , (12.36% ;1940 Kg/m^3) , (8.57% ;1930 Kg/m^3) , (8.73% ;2080 Kg/m^3) , (11.86% ;2150 Kg/m^3) , (7.73% ;1820 Kg/m^3) , (6.10% ;1840 Kg/m^3) and (6.29% ;1720 Kg/m^3) respectively. The quarry dust and granite were not easy to compact due to their hard nature and their inability to hold or retain moisture. It must also be noted that excessive compaction causes particles breakdown, it reduces permeability and also increases the percentages of fines to an amount greater than the special limit.

The results of Specific gravity of the granular filter materials are arranged in descending order below: Granite (3.98) > Gravel (3.02) > River sand (2.85) > Gutter sand (2.84) > Stone dust (2.82) > Sharp sand (Ile ewe) (2.80) > Peat sand (Ile ewe) (2.75) > Peat sand (Ago) (2.73) > sharp sand (2.70). The higher the specific gravity the larger the percentage of fine materials present. Apart from commercially sourced aggregate (granite), gravel also has a very large fine materials as also observed in its Atterberg tests results.
The Permeability Coefficients were; 3.54×10^{-5}cm/s, 3.14×10^{-5}cm/s, 3.59×10^{-5}cm/s, 3.64×10^{-5}cm/s, 2.59×10^{-5}cm/s, 3.09×10^{-5}cm/s, 2.87×10^{-5}cm/s and 2.78×10^{-5}cm/s respectively. It must be noted that constant head permeability could not be performed on granite. In such case where core cracking is a possibility, then high capacity drains with appropriate filters are required. A filter could be constructed with permeability close to the adjacent fine- grained fill or foundation material to prevent internal erosion.

CONCLUSIONS

The locally sourced granular materials are adequate and suitable to serve as filter materials, with relatively low cost compared to commercially sourced aggregates. The filter materials met the retention (piping or stability) and criterion. It is recommended that sand-gravel pack with top size of 12.7-19.0mm (1/2 -3/4 inch) can be used as drain, especially, the gravel from Ogbomoso and granite from Osogbo.

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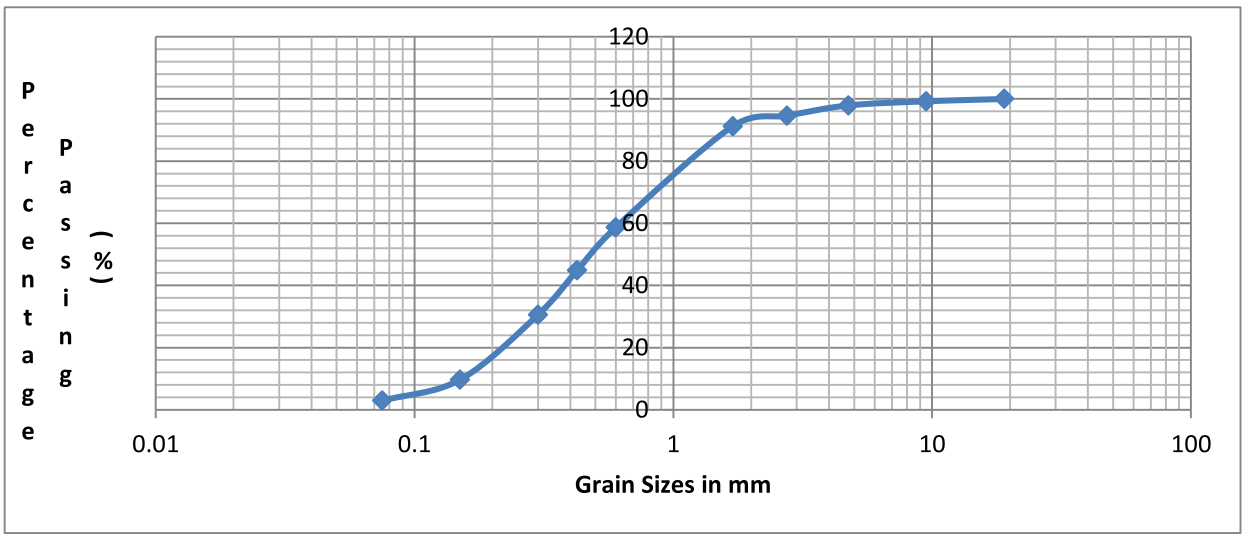

Figure 1: Grain Size graph of Peat sand from Ago Area Ogbomoso

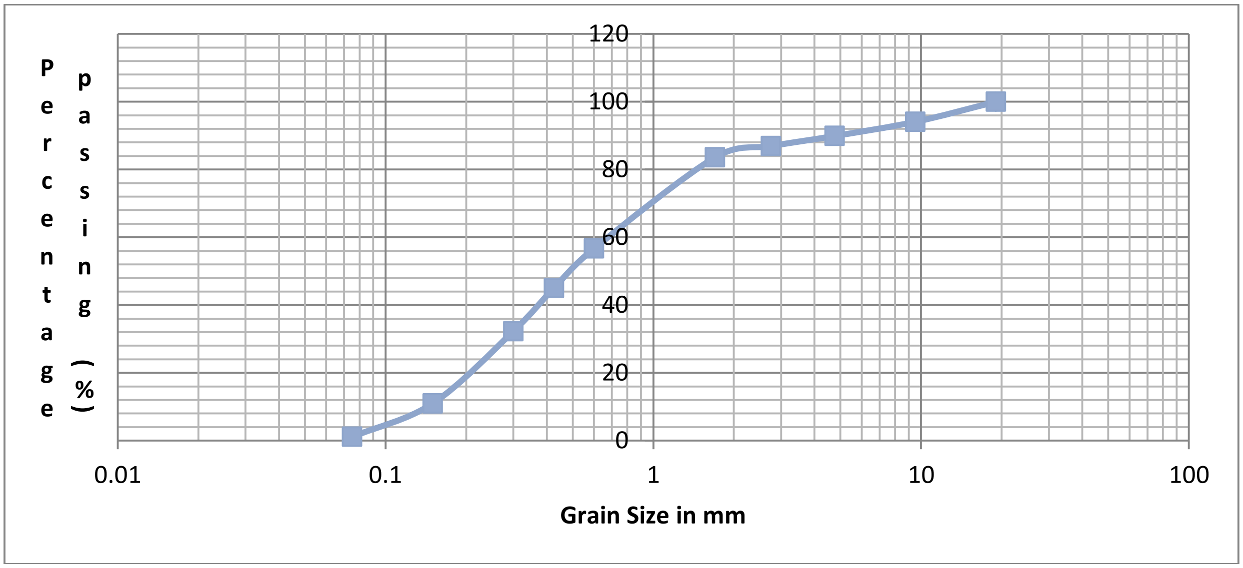

Figure 2: Grain Size graph of Sharp sand from Ago Area Ogbomoso

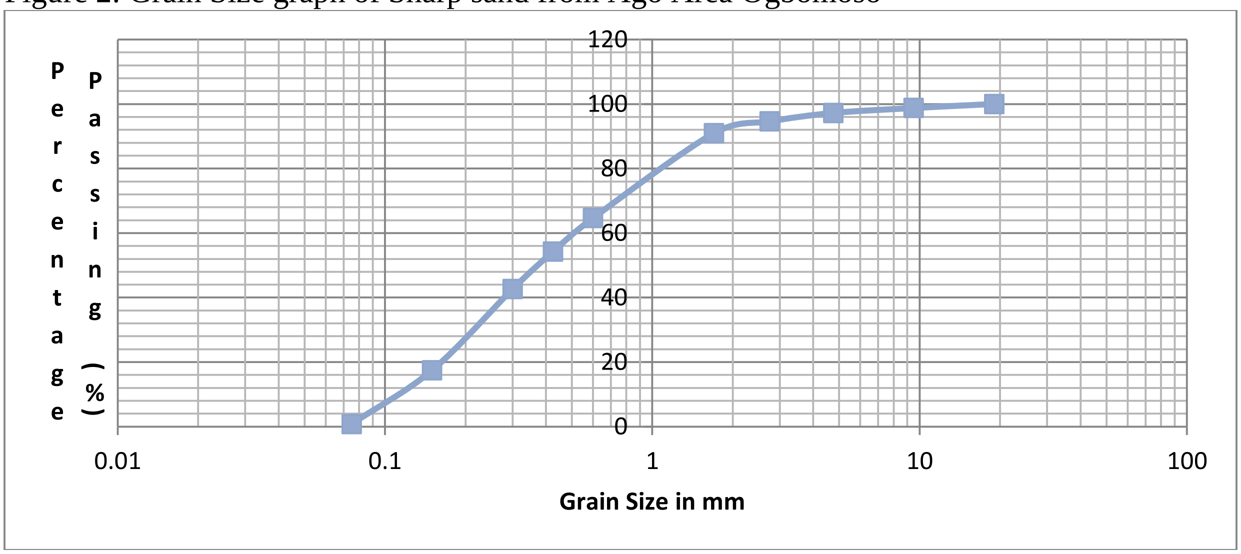

Figure 3: Grain Size graph of Peat sand from Ile ewe Ogbomoso

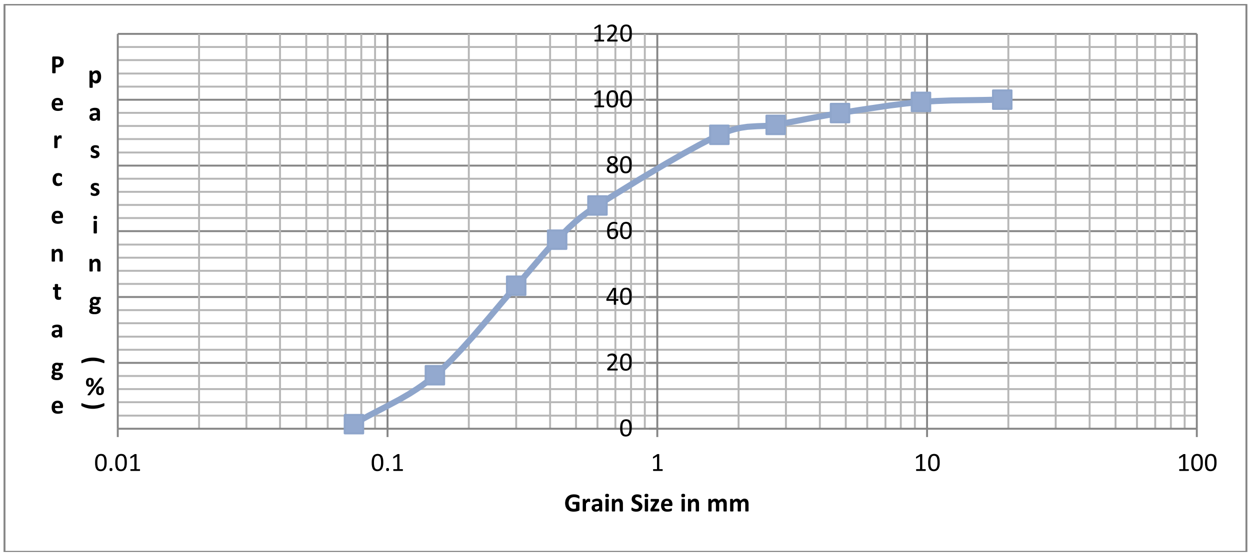

Figure 4: Grain Size graph of Sharp sand from Ile ewe Ogbomoso

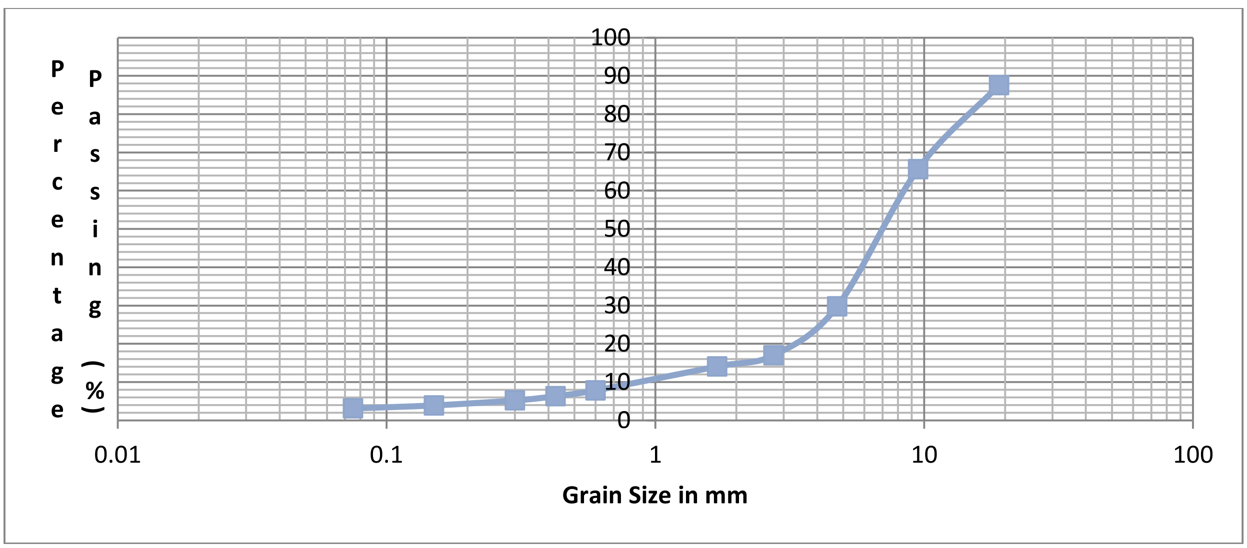

Figure 5: Grain Size graph of Gravel from Ago Area Ogbomoso

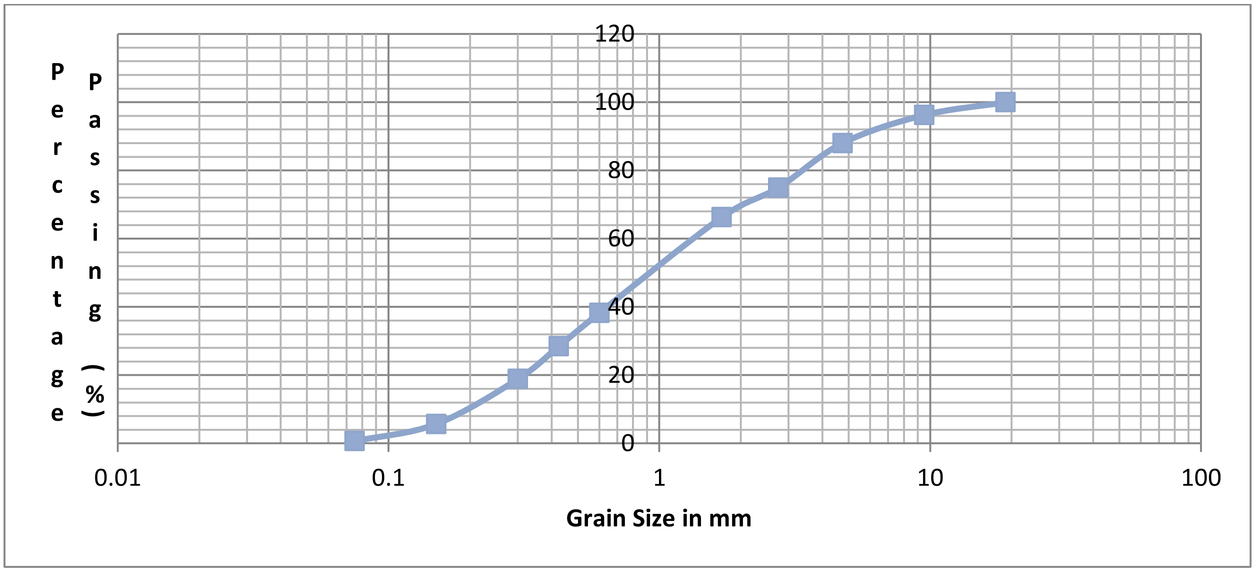

Figure 6: Grain Size graph of Gutter Sand from Power Line Area Osogbo

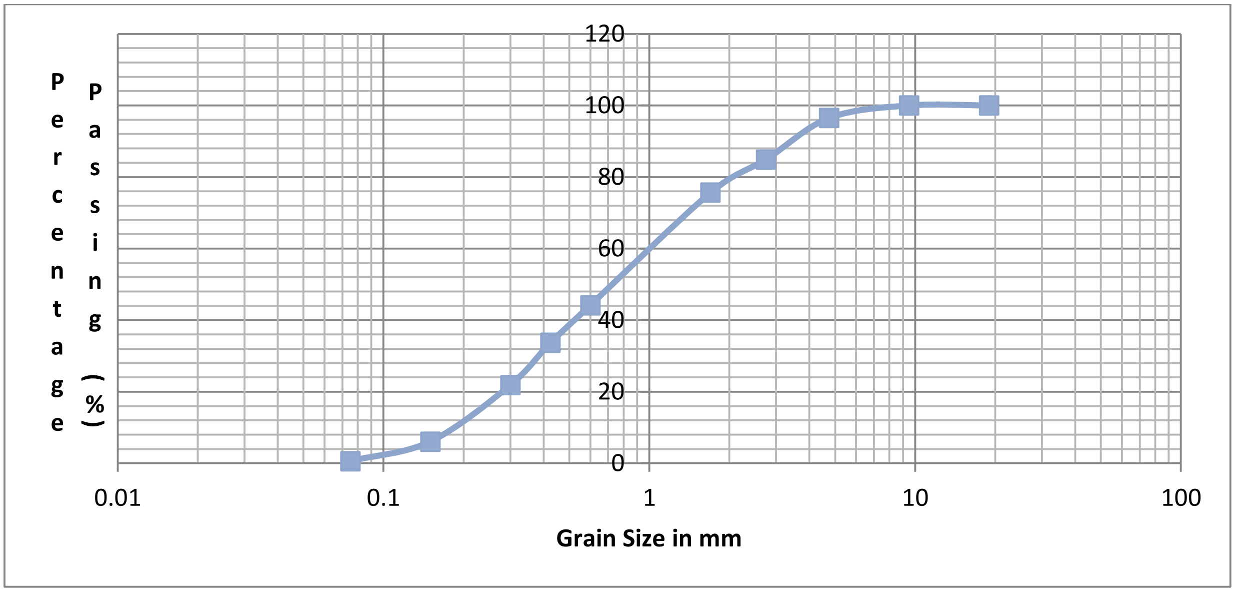

Figure 7: Grain Size graph of River Sand from Power Line Area Osogbo

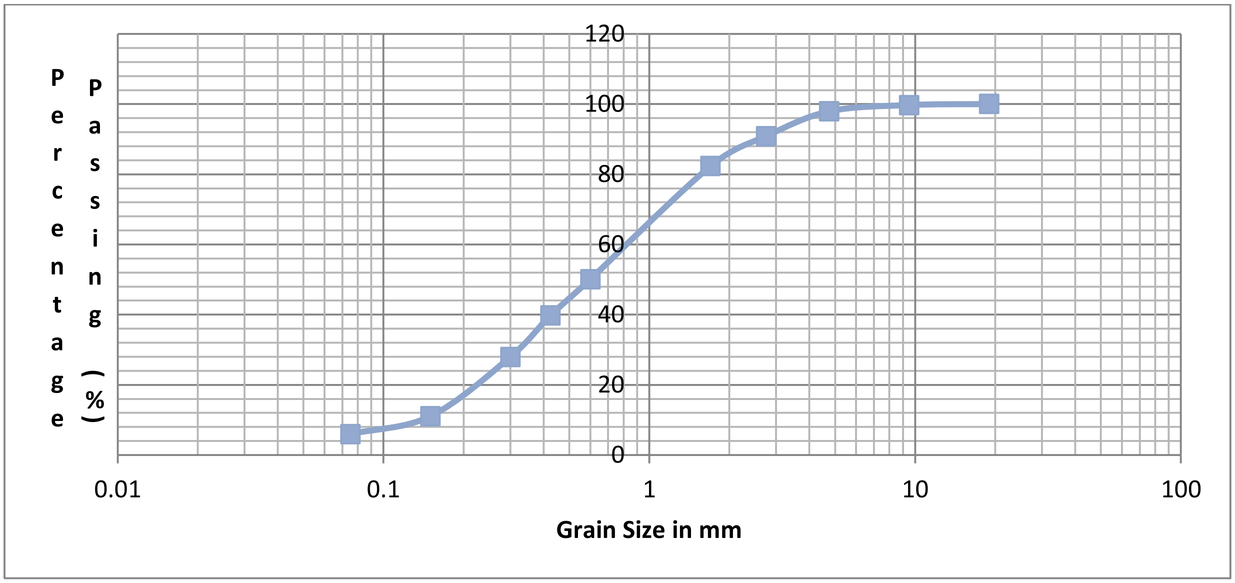

Figure 8: Grain Size graph of commercially sourced Stone dust from Osogbo

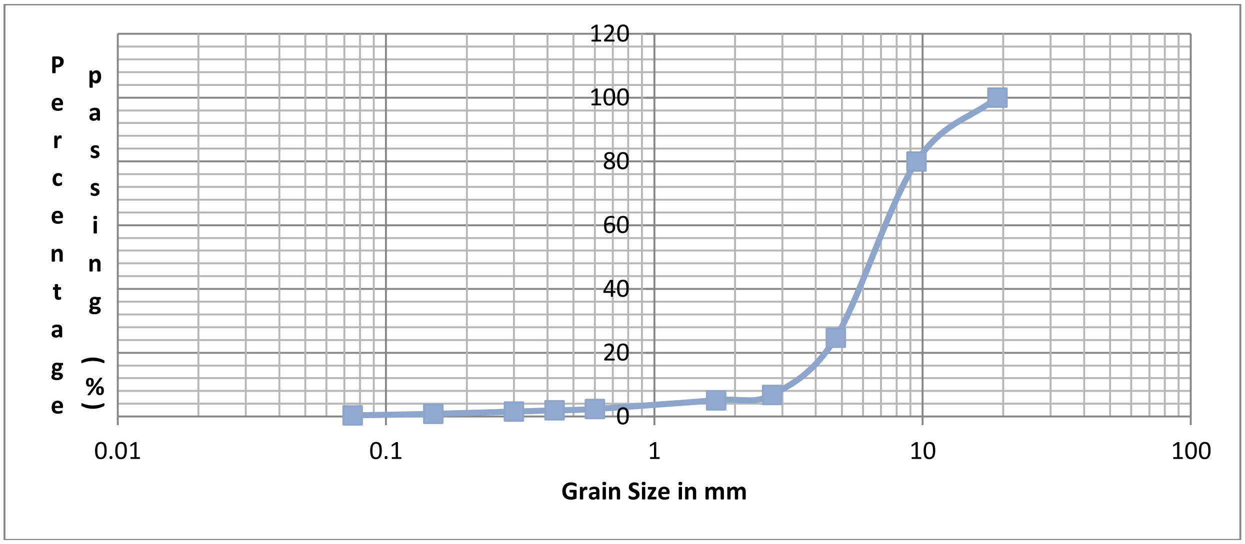

Figure 9: Grain Size graph of commercially sourced Granite Stone from Osogbo

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Table 1: Result of the Geotechnical Properties of Granular filters and drain

	Peat sand from Ago area Ogbomoso	**Sharp sand from Ago area Ogbomoso**	**Peat sand from Ile-ewe Ogbomoso**	**Sharp sand from Ile-ewe Ogbomoso**	**Gravel from Ago area Ogbomoso**	**Gutter sand from Power line Osogbo**	**River sand from Power line Osogbo**	**Stone dust from Min. of Works Osogbo**	**Granite from Min. of Works Osogbo**
Particle size analysis:									
% passing # 200	2.94	1.12	0.81	1.35	3.13	0.68	0.58	5.93	0.32
% passing # 4	97.92	89.91	97.22	95.90	26.76	88.05	96.50	97.93	24.71
Specific gravity	2.73	2.70	2.75	2.80	3.02	2.84	2.85	2.82	3.98
Compaction Tests:									
MDD (Kg/m^3)	1830	1960	1940	1930	2080	2150	1820	1840	1720
OMC (%)	5.11	6.57	12.36	8.57	8.73	11.86	7.73	6.10	6.29
Atterberg Limits:									
Liquid limit	17.00	13.00	19.00	15.00	24.50	19.09	24.90	24.90	25.00
Plastic limit	11.27	6.06	10.83	8.89	16.13	18.50	22.43	22.44	14.24
Plasticity Index	5.73	6.94	8.17	6.11	8.37	0.59	2.47	2.48	10.76
Permeability	$3.54x10^{-5}$	$3.14x10^{-5}$	$3.59x10^{-5}$	$3.64x10^{-5}$	$2.59x10^{-5}$	$3.09x10^{-5}$	$2.87x10^{-5}$	$2.78x10^{-5}$	-