Properties of Pumice Lightweight Aggregate

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Abstract

The use of Lightweight concretes has gained acceptance and popularity world wide in the recent years in the construction and development of both the infrastructure and residential buildings. The properties of volcanic pumice lightweight aggregates obtained from Longonot in Mai Mahiu area in Kenya was experimentally investigated and this study presents the experimental results of the investigation. Three samples of the lightweight aggregates were investigated and their properties compared with those of the conventional normal aggregate. In this experimental investigation the physical and mechanical properties of the aggregates were investigated. Properties such as bulk density, water absorption, grading and aggregate impact crushing value were determined.

Keywords: Pumice; Lightweight Aggregate, Bulk Density, Grading

1.0 Introduction

In concrete production aggregate is the cheaper material as compared to cement and maximum economy is obtained by using as much aggregate as possible. Aggregates also improve the volume stability and the durability of the resulting concrete. A good aggregate should produce the desired properties in both the fresh and hardened concrete. An aggregate therefore requires to be adequately tested to ensure it has the desired properties hence a truly representative sample is required sampling was carried out in accordance with BS812 [7]. The Volcanic Pumice used for the production of the concrete for this research was obtained from Mount Longonot in Nakuru County, in Kenya. Mt. Longonot is a dormant volcanic mountain with huge deposits just below the shallow vegetation.

During the Roman Empire, the Romans used lightweight aggregates for the production of lightweight concrete as a light construction material. The earliest development of lightweight concrete was designed using the locally available lightweight aggregates to the Romans which were the Grecian and Italian pumice. Since that time there has been advancement in the production of lightweight concrete using either the naturally occurring lightweight aggregates such as pumice or the use of artificial lightweight aggregates. During the 20th century there was marked development in the use of lightweight concrete. It is reported that during the World Wars the military engineers took advantage of the lightweight of concrete produced using natural lightweight aggregates notably pumice to produce concrete which was used in the construction and production of ships and barges which were light and consequently had improved load carrying capacity [1].

The need for the construction of cheaper structures has increased the demand for the use of lightweight concrete which is generally lighter and results in savings in the cost of foundations due to the reduction in the self weight of the various structural elements such as slabs and beams [2] in Kenya the cost of lightweight concrete unlike in the other countries are cheaper as the pumice aggregates cost approximately two thirds of the cost of normal aggregates.

The common types of lightweight concretes produced in Kenya are composed of pumice lightweight coarse aggregates obtained by simple extraction using shovels from natural sources and river sand or rock sand as fine aggregates.

Pumice is notably one of the most common and the oldest of naturally occurring aggregates utilized lightweight coarse aggregates used for the production of concrete for construction industry. The term pumice is a generic term used to describe porous solids produced during the cooling of magma as a result of volcanic activation the voids are as result of the outflow of gases from the magma produces. Because of the gases small hollow voids renders the resulting solids to have a very porous structure, and this is why pumice has high porosity and absorption. Various studies have been conducted od pumice lightweight aggregate concretes all over the World with most researchers concentrating on the locally available materials in their areas or countries.

Most researchers have concluded that pumice can be used to produce semi-structural grade lightweight concrete [2] Compressive strength (28 days) up to 55MPa was achieved incorporating Turkish pumice aggregates [3]. Besides, the effectiveness of pumice lightweight aggregates concrete has been shown for structural wall panels [2].

The aim of this paper is to study the properties of volcanic pumice lightweight aggregate obtained from Mahiu area of Naivasha in Nakuru County. The physical and mechanical properties of the aggregates are investigated.

2.0 Methodoly

2.1 Overview

Various experiments were carried out in the laboratory on the pumice lightweight aggregates in order to investigate their suitability as aggregates for concrete and to determine their quality, mechanical and physical properties, these were: grading, bulk density, silt content, organic matter content, fineness modulus and water absorption.

2.2 Grading

The grading of an aggregate has a considerable effect on the workability and stability of a concrete mix and it is for this reason that grading of both the pumice lightweight aggregate and the normal aggregate was carried out to establish whether pumice qualifies as an aggregate according to BS 882[5]. The following procedure was followed in the grading of the aggregate;

Three samples from different loads as delivered were graded to determine whether they lie within the limits of the envelope for the grading of course aggregates, this was necessary because pumice lightweight aggregates are not crushed but used as obtained from the source where it is simply scooped using shovels. The results obtained are shown in figures 2.2.1 to 2.2.6. The aggregates grading curves show suitable agreement and correspondence well with the standard grading envelopes in BS882[5]. Grading was also carried on normal aggregates and the results in figures2.2.1to 2.2.6.

2.2.1 Pumice Aggregate

Table 2.2.1 SAMPLE 1

Grading of Course Aggregates (pumice)			
Sieve(mm)	lower limit %age passing	upper limit %age passing	Sample %age passing
37.5	100.0	100.0	100.0
20.0	90.0	100.0	89.2
10.0	30.0	60.0	30.3
5.0	0.0	10.0	6.3

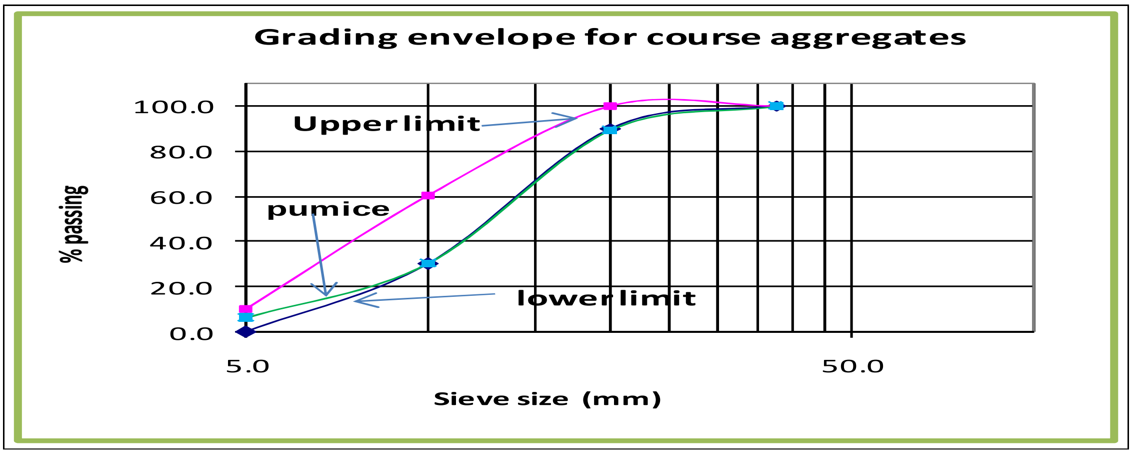

Figure 2.2.1

Table 2.2.2: Sample 2

Grading of Course Aggregates (pumice)			
sieve	lower limit	upper limit	sample
37.5	100.0	100.0	100.0
20.0	90.0	100.0	89.2
10.0	30.0	60.0	27.9
5.0	0.0	10.0	9.7

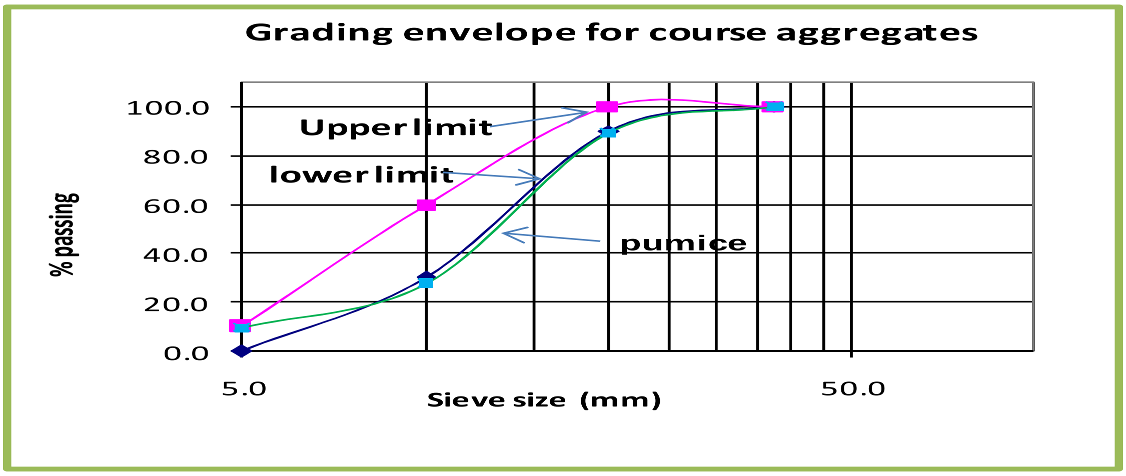

Figure 2.2.2

Table 2.2.3: Sample 3

Grading of Course Aggregates (pumice)			
sieve	lower limit	upper limit	sample
37.5	100.0	100.0	100.0
20.0	90.0	100.0	92.9
10.0	30.0	60.0	40.7
5.0	0.0	10.0	10.8

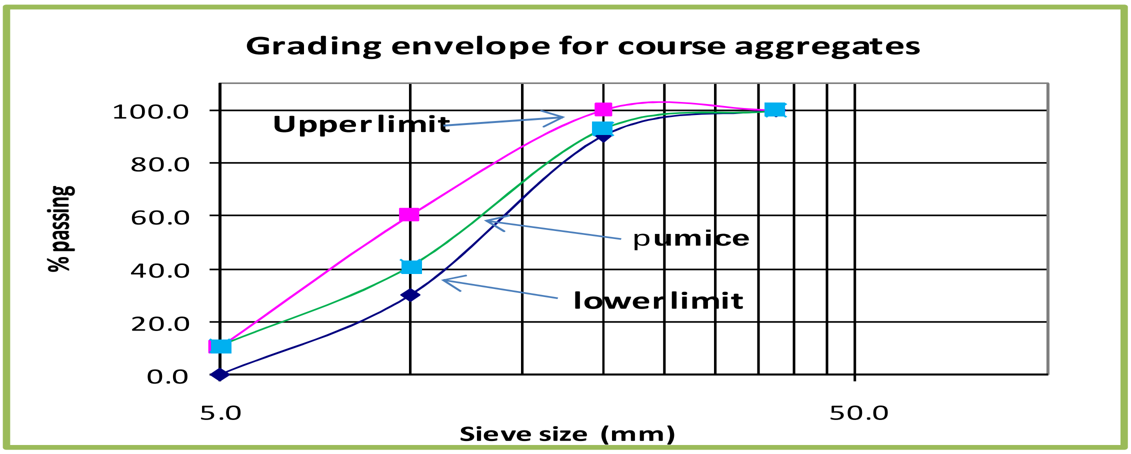

Figure 2.2.3

Normal Aggregate

Table 2.2.4 **Sample 1**

Grading of Course Aggregates			
sieve	lower limit	upper limit	sample
37.5	100.0	100.0	100.0
20.0	90.0	100.0	99.4
10.0	30.0	60.0	50.4
5.0	0.0	10.0	2.4

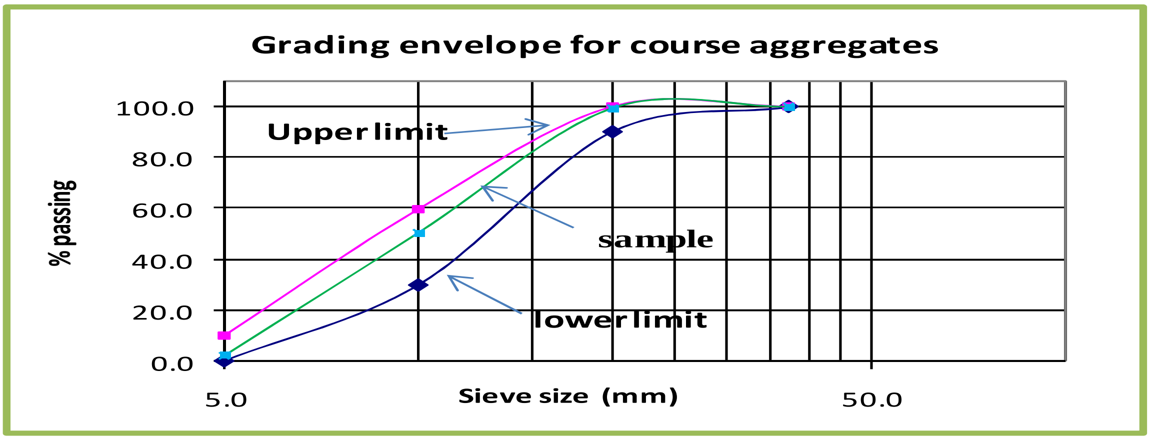

Figure2.2.4

Table2.2 5: Sample 2

Grading of Course Aggregates			
sieve	lower limit	upper limit	sample
37.5	100.0	100.0	100.0
20.0	90.0	100.0	98.8
10.0	30.0	60.0	54.1
5.0	0.0	10.0	4.9

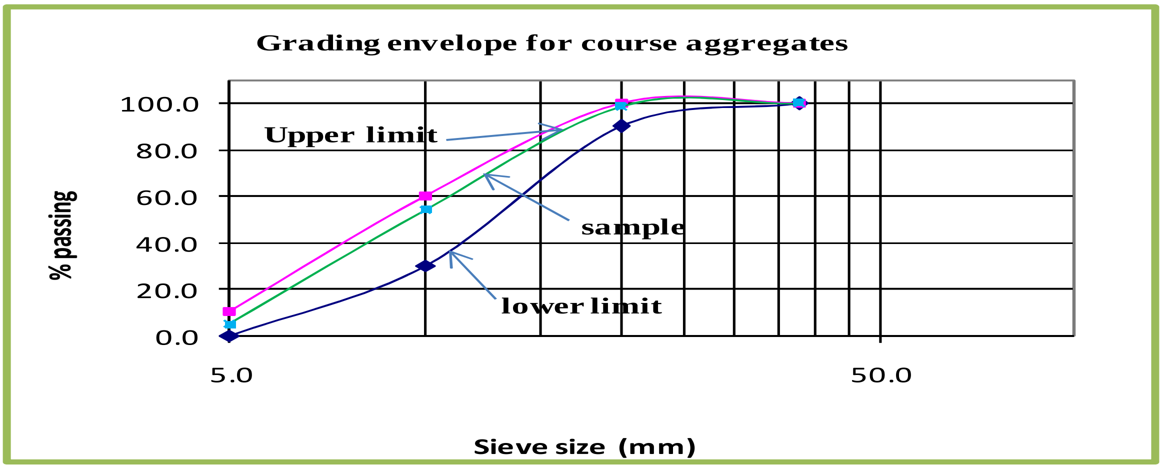

Figure 2.2.5

Table 2.2.6: Sample 3

Grading of Course Aggregates			
sieve	lower limit	upper limit	sample
37.5	100.0	100.0	100.0
20.0	90.0	100.0	100
10.0	30.0	60.0	60.6
5.0	0.0	10.0	8.1

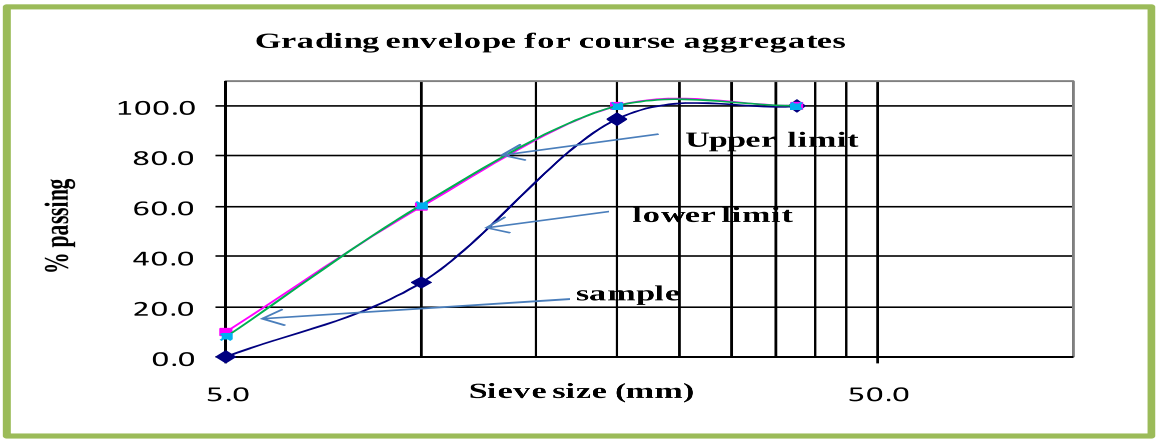

Figure 2.2.6

2.3 Flakiness of Lightweight Aggregates

Flakiness index of an aggregate is the percentage by weight of particles in it whose least dimension (thickness) is less than three-fifth of their mean dimension. It was measured on particles passing through mesh size of 63 mm and retained on mesh size 6.3 mm. enough quantity of dry blended sample was taken so that at least 200 pieces of any fraction was present.

Table2.3 (i):.Sample 1

FLAKINESS INDEX (FI)			
Test sieve	**Mass retained (m1)**	**Flakiness sieve**	**Mass passing (m3)**
37.5	0.0	26.3	0.0
20.0	215.5	14.4	2.0
10.0	1178.5	7.2	35.0
5.0	479.0	4.9	81.0
	1872		**118.0**
Flakiness index (FI)			**6.3**

Table 2.3(ii):Sample 2

Flakiness index (FI)			
Test sieve	**Mass retained (m1)**	**Flakiness sieve**	**Mass passing (m3)**
37.5	0.0	26.3	0.0
20.0	216.0	14.4	32.0
10.0	1226.0	7.2	52.0
5.0	363.5	4.9	78.0
	1805.5		**162.0**
Flakiness index (FI)			**9.0**

Table 2.3(iii):Sample 3

FLAKINESS INDEX (FI)			
Test sieve	**Mass retained (m1)**	**Flakiness sieve**	**Mass passing (m3)**
37.5	0.0	26.3	0.0
20.0	142.5	14.4	8.0
10.0	1044.5	7.2	66.5
5.0	598.0	4.9	135.0
	1784		**209.5**
Flakiness index (FI)			**11.7**

Table 2.3(iv):Sample 2

FLAKINESS INDEX (FI)			
Test sieve	**Mass retained (m1)**	**Flakiness sieve**	**Mass passing (m3)**
37.5	0.0	26.3	0.0
20.0	32.5	14.4	16.0
10.0	960.0	7.2	294.5
5.0	958.5	4.9	576.5
	1951.0		**887.0**
Flakiness index (FI)			**45.5**

Table 2.3(v)

FLAKINESS INDEX (FI)			
Test sieve	**Mass retained (m1)**	**Flakiness sieve**	**Mass passing (m3)**
37.5	0.0	26.3	0.0
20.0	25.0	14.4	0.0
10.0	893.5	7.2	252.5
5.0	984.5	4.9	575.0
	1903.0		**827.5**
Flakiness index (FI)			**43.5**

Sample 3
Table 2.3(vi):

FLAKINESS INDEX (FI)			
Test sieve	**Mass retained (m1)**	**Flakiness sieve**	**Mass passing (m3)**
37.5	0.0	26.3	0.0
20.0	0.0	14.4	0.0
10.0	787.5	7.2	214.0
5.0	1050.5	4.9	632.0
	1837.5		**846.0**
Flakiness index (FI)			**46.0**

FI=M4/M2

NOTE:
1. M2= Total summation of retained mass
2. M4= Total summation of passing mass

2.4 Calculation of Aggregate Flakiness Index

The flakiness index of both the pumice lightweight aggregates was carried out in according to the procedure set out in BS 812 the results are reported in table 2.3(i) to table 2.3(vi). The flakiness index of the respective aggregate sample was then calculated as;

Flakiness FI = $\frac{m_4}{m_2} \times 100$ for the whole sample, Although the flakiness can also be calculated as follows;

Flakiness FI= $\frac{m_3}{m_1} \times 100$ for each size fraction

2.5 Dry Density of the Aggregate

The determination of dry density of the pumice lightweight aggregate was carried out in accordance with the requirements of BS 812 Part 100 [6].The pumice lightweight aggregate sample was prepared in accordance with BS

812 Part 102[7].The container used was 1000cc and the dimensions conformed to those stipulated in Clause 6.3.1 BS 812 Part 102[7].The results obtained were then analyzed as required.

Table 2.5

ITEM	TEST No.1	TEST No.2	TEST No.3
Volume of container (cc)	9800	9800	9800
Mass of container (g)	4636	4636	4636
Mass of aggregate + container (g)	10200	10400	10200
Mass of aggregate (g)	5564	5764	5564
Dry density of aggregate (kg/m^3	567.8	588.2	567.8

Average density of the pumice aggregate $= \left(\dfrac{567.8 + 588.2 + 567.8}{3} \right)$ =574.6 kg/m^3

2.6 Specific Gravity

Specific gravity was determined in accordance with BS 812 Part 102[7].In summary; a sample of about 1kg of the aggregate was thoroughly washed to remove material finer than 0.075mm. The washed material was then placed in a tray and water added until the water covered it all. The aggregate was then agitated vigorously and immediately the wash water was poured over the sieve which had been previously wetted on both sides. This operation was repeated until the wash water was clear with any material being retained on the sieve returned to the sample. The washed sample was transferred to a tray and water added until it was fully immersed, any entrapped air being removed by gentle agitation with a rod. The sample was then left immersed in water for 24 hours. The water was then carefully drained by decantation through a 0.075mm test sieve; the aggregate was exposed to warm air to evaporate surface moisture and stirred frequently to ensure uniform drying until no free surface moisture could be seen. A part of the sample was the placed in the pycnometer and weighed (M2), the pycnometer was then filled with water, the cone was then screwed on and any entrapped air removed by rotating it on its side, the hole at the apex being covered with a finger, the bottle was then dried on the outside and weighed (M3). The pycnometer was then emptied and refilled with water and weighed (M4). The pycnometer was then weighed empty (M1).This process was repeated three times, and results recorded and analyzed accordingly.

Table 2.6 Specific Gravity Test Results

	MASS		
CONTENTS	SAMPLE1	SAMPLE 2	SAMPLE3
Mass of empty container (g)	506.5	506.5	506.5
Mass of container + Aggregate (g)	1006.0	1005.5	1006.0
Submerged weight (g)	534.5	527.0	555.0
Mass of aggregates (g)	491	490	491
Specific Gravity	1.06	1.04	1.07

AVERAGE SPECIFIC GRAVITY $= \left(\dfrac{1.06 + 1.04 + 1.07}{3} \right) = 1.06$

2.7 Water Absorption

Water absorption was carried out as per procedure in BS 812 Part 102[7].In summary the sample was washed while in 75 µmm sieve to remove any material passing through this sieve the sample was then dried at room temperature, the objective of the cleaning was to remove any material which would be lost during the draining process. The sample was then weighed and placed in a container the sample and the container were, then immersed in water ensuring that the sample is adequately covered by water. The period of immersion in water was then taken after which the sample was removed from the tank and allowed to drain to ensure that there is no trapped water in the sample it then was weighed and re-immersed in water again and the process was continued at 5, 10, 15, 30, and 60 minutes and the data recorded in Table 14. Final calculations were done as per procedure.

Table 2.7 water absorption test results

AVERAGE ABSORPTION							
Time(min)	0	5	10	15	30	60	1440
Absorption %	0	31.11	32.34	32.98	33.17	33.26	46.12
Total absorption %		52.88	55.95	57.54	58.03	58.27	100

Wt. of aggregate +water	768	1066	1083	1084	1086	1087	1299
Wt. of water absorbed (g)	0	149	157.5	158	159	159.5	265.5
Absorption %	0	33.18	34.43	34.50	34.64	34.71	46.95
Total absorption %		56.12	59.32	59.51	59.89	60.08	100

3.0 Results and Discussions

3.1. Grading

The grading of any aggregate has a considerable effect on the workability and stability of a concrete mix. The grading of both the pumice lightweight aggregate and the normal aggregate was carried out according to BS 812-102[7].

From the results of sieve analysis tests it was found that the coarse pumice aggregate compares well with normal crushed aggregate.

3.2 Dry Density of the Aggregate

The results of the dry density test on pumice lightweight aggregate carried out in accordance with the requirements of BS 812 Part 100 [6]. The dry density was obtained as 574.5Kg/m^{3}from the results it can be seen that pumice coarse aggregate is much lighter than the normal weight aggregate used for the production of normal weight concrete whose dry density was established to be 574.5Kg/m^3. From the results it was established that pumice lightweight aggregate from Mai Mahiu in Naivasha Kenya satisfies the requirements of ASTMC 330[10] for lightweight coarse aggregate for structural concrete which is in the range of 560 to 1120kg/m^3

3.3 Specific Gravity

The specific gravity of this type of volcanic pumice aggregate was determined as 1.06,this value is more than 50% lower when compared to the specific gravity value of normal weight aggregates of 2.6 as tabulated in DOE document [9] .

3.4 Water Absorption

The water absorption after 15 minutes for the above cases is 30.15%, 32.05%, 34.50%, and 35.21% this gives average water absorption of 32.98% after 15 minutes giving adequate time for mixing the concrete.

The water absorption test results given in Table 2.7 indicate that the water absorption of volcanic pumice aggregate is far much higher than for normal aggregate.

4.0 Conclsion

Pumice aggregates meet the physical properties of concrete aggregates and can effectively be used as lightweight aggregates and that the concrete which can be produced with these aggregates satisfies the requirements of low lightweight concrete. Further that the concrete produced can safely be used for the construction of domestic houses, where loads are light and high strength is not required. The pumice aggregates available in this country have a potential to produce commercially low lightweight concrete and there is an abundant resource on naturally occurring lightweight aggregate for commercial exploitation.

Other physical and mechanical properties of aggregates, reveal that the dry bulk density of lightweight aggregate is in the allowable range, however it is close to the maximum

References

1) Methods for Determination of Particle Size Distribution. Sieve Tests BS812
2) Kluge RW, Sparks, MM, Tuma EC Lightweight-aggregate Concrete. ACI Journal, Proceedings No. 945 (1945), 625-44
3) Hossain KMA, Lachemi M. Design, Strength, Durability and Fire Resistance of Lightweight Concrete with Pumice Aggregate ACI Materials Journal No. 5, 104(2007) 449-57
4) Concrete Technology Level 4, J.G. Gunning,ISBN10:0582412331, Longman (1983)
5) Specification for Aggregates from Natural Aggregates from Natural sources for Concrete BS882 (1983)
6) General Requirements for Apparatus and Calibration, BS812 Part 100 (1990). Testing of Aggregates.
7) Methods for Sampling Aggregates BSI BS812 Part 102: Testing Aggregates
8) Concrete Structures. Standards Australian, 2001,AS3600
9) Department of Environment 'Design of Normal Concrete Mixes' HMSO London 1975.
10) Specifications for Lightweight aggregates for structural concrete, Annual Book of ASTMC Standards 330-00,philadephia,USA