AN OVERVIEW OF SCORIA LIGHTWEIGHT AGGREGATE CONCRETE

Sani M. Bida[1], Musa Muhammad[1], Aliyu A. Vulegbo[1], Adamu Yunusa[2]

[1]Department of Civil Engineering, School of Engineering Technology, Federal Polytechnic Bida

[1]Department of Quantity Surveying, School of Environmental Studies, Federal Polytechnic Bida

E-mail: informsani@yahoo.com

ABSTRACT: *Generally, the use of LWA in concrete lowers its density and therefore reduces the overall dead weight on the entire structure resulting to lower cost of the structure. This paper is an overview of the performance of scoria as aggregate in concrete and behaviour variety of different additives in the composite in an effort to improve its properties. The performance of scoria aggregate in concrete was found to be highly appreciable and could be improved by controlling the water content, pre-soaking, silica fume and fly ash.*

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INTRODUCTION

The use of LWAC in building has a long time history which is dated back to 3000BC during the Indus Valley civilization when Mohenjo-Daro and Harappa were constructed using LWA material (www.ide.titech.ac.jp). In Europe, the use of LWA can be traced back to 2000 years when the Roman Empire built Colloseum and Pantheon with material partly of LWA whereas in USA, over 100 war ships were built during the world war II in LWAC structures ranging in capacity from 3000 to 140,000 tons and their effective functioning has led to the extended use of structural LWA in buildings and bridges (www.ide.titech.ac.jp; Ries *et al.* (2010) Mijnsbergen *et al.* (2000). Selma, one of the LWAC ships built is 132.3m long has compressive strength and density of 38.5MPa and 1905Kg/m^3 respectively and require about 236x10^{6}kg of LWAC Wilson & Malhotra, (1988). According to Ries *et al.* (2010), structural LWAC has been used for over 2000 years and has been wide spread for the past 90 years and it structural efficacy has contributed to the sustainable development by optimizing design and construction effectiveness, increased durability of the products during their service life and reduced transportation requirement. Investigation by Mijnsbergen *et al.* (2000) on the properties of lightweight concrete has shown good potentiality when applied in structural buildings. Most of the LWAs used in the early years were of natural origin and were obtained from volcanic cooled lava which has solidified to form a rock. Some of these materials are pumice, scoria, tuff, etc and which use depends on availability. Recently, more research efforts and interest have been developed on the use of LWAC due of some important properties found in them. Alduaij *et al.* (1999) reported that the existence of global environmental, economic and technical motivations to encourage the applications of lightweight concrete as a low density product cannot be over emphasised as it reduces the self-weight, foundation size and construction costs. Yasar *et al.*, (2003) also reported that a reduction in the self-weight of structural components by the use of lightweight aggregates could result in a reduction of the cross-section area of the structural members coupled with apparent benefits of higher strength/weight ratio, tensile strain capacity, lower coefficient of thermal expansion, and higher heat and sound absorption features due to air voids of the LWAC. Aggregate proportion play very important role in concrete, it occupies about 70% of concrete volume, therefore, concrete density may depends on the density of aggregates used for its production and subsequently contributes considerably to the structural performance of concrete structures. Lo and Cui, (2004) reported that LWAC is a multidimensional material for construction, which offers a variety of technical, economic, environment-enhancing and conserving advantages and it is becoming a dominant material for construction in the new global dimension.

SCORIA AGGREGATE

Neville (2008) described scoria as a vesicular glassy rock which is like industrial cinder. It is a Greek word which means (rust) which is a dark coloured vesicular volcanic rock which may be crystalline or non-crystalline and is denser than pumice due to its larger and thicker vesicular walls and a typical of scoria is shown in Fig. 1 revealing it porous nature. It has specific gravity greater than 1 and therefore, sinks in water. Its porous nature enables it to provide better grip between the aggregates than normal weight aggregate, but absorb water thereby decreasing workability of the concrete. Mijnsbergen *et al.* (2000) revealed that during the forties and fifties, a number of single family houses were built from scoria and pumice block but resulted in failure due to lack of knowledge of the material and misuse under freeze-thaw condition. But, the later attempt in 1980 to produce LWAC elements such as walls and roof unit as secondary structural units with the same material was a break through and further research on the material took a new global dimension.

Fig. 1: Pumice aggregate (http://geology.com/rocks/pumice.shtml)

PROPERTIES OF SCORIA AGGREGATE

Hossain, (2006a; 2006b) reported the specific gravity of scoria to be 2.15 while Yasar *et al.*, 2003 and Kilic *et al.*, 2003 reported a higher value of 2.59. It is observed that from the few works undertaken on scoria aggregate, it density and specific gravity are higher than that of pumice aggregate. From Table 1, the lowest specific gravity obtained on pumice is 0.82 as compared with scoria of 2.15. More so, the highest specific gravity of scoria aggregate as shown in Table 1 is 2.59 which are in the range of specific gravity of normal weight aggregate of 2.4-2.65. This may be the reason for low patronage in researches on scoria aggregate. Density of material is one of the most important physical properties that encourages research activity due to it advantage of reduced total weight of the composite produced. Some researchers such as Gunduz (2008) reported that the dry bulk density for fine and coarse scoria aggregate is 1010 and 765 kg/m^3 and water absorption value of 23 and 29% for fine and coarse scoria aggregate respectively while Kilic *et al.* (2003) obtained bulk dry unit weight of 1518 Kg/m^{3}and water absorption of about 20%.

Table 1: Physical Properties of Scoria Aggregate

Name of author/year	Material Used	Density (Kg/m^3)	Specific gravity	Water absoption (%)	Loss Angeles Abration (%)
Atis *et al.* (2003)	scoria	1518	2.59	17	-
Yasar *et al.* (2004)	scoria	1518	2.59	-	-
Hossain (2006)	coarse scoria	1556	2.15	35.6	30
	fine scoria	1885	-	22.2	-
Gunduz (2008)	coarse scoria	765	-	29	-
	fine scoria	1010	-	23	-

COMPRESSIVE STRENGTH OF SCORIA AGGREGATE

The suitability of scoria in concrete as fine and coarse aggregate was investigated and found to be adequate for use as structural lightweight concrete as it have adequate strength and density (Hossain, 2006). It was found to satisfy the requirement set as per ASTM C330 aggregate for structural lightweight concrete. The compressive strength of scoria concrete was investigated by Yasar *et al.* (2004) by using cement to scoria aggregate ratio of 1:2.5 and water binder ratio of 0.55. Fly ash and silica fume of 20% and 10% respectively was used as partial replacement of Portland cement by weight and 28 day compressive strength of about 37MPa was achieved. When scoria aggregate percentage replacement varies from 0-100% by volume, the cube compressive strength reduced from 40-28MPa at 28day and coarse scoria aggregate replacement between 50-100% by volume yield compressive strength beyond 15MPa with concrete air dry density between 1850-2150 kg/m^3. Table 2 show results obtained by various researches with the maximum 28-day compressive strength of 38.2MPa and minimum of 28MPa. Moufti *et al.* (2000) reported that by using water cement ratio of 0.78, 1% Cico Fluid FG as admixture and silica fume of 10% as partial replacement of cement, a 28-day compressive strength of 38.2MPa was achieved.

Table 2: Mechanical Properties of Scoria Concrete

Author	code	Water cement ratio	Mix ratio	scoria %	Additive,	Compressive strength (Mpa)	Tensile strength (Mpa)	Fresh density (Kg/m^3)
Moufti *et al.* (2000)	Mix 1	0.9	-	100	10% SF	35.8	-	1740
	Mix 2	0.85	-	100	10% SF	37.2	-	1629
	Mix 3	0.78	-	100	10% SF	38.2	-	1706
Atis *et al.* (2003)	M1	0.55	01:02.5	-	-	28	6.7	1955
	M2	0.55	01:02.5	-	20% FA	29.2	6.8	1932
	M3	0.55	01:02.5	-	10% SF	38.9	8.2	1944
	M4	0.55	01:02.5	-	20% FA, 10% SF	36.8	8.3	1913
Hossain (2006)	A-100	0.45	-	42.6	-	28	-	1845
	A-90	0.45	-	36.5	-	30	-	1963
	A-75	0.45	-	28.5	-	32	-	2022
	A-50	0.45	-	17.1	-	35	-	2135
	A-0	0.45	-	0	-	40	-	2520

Table 3 shows the spectrum of lightweight concrete adopted from ACI 213 which classified the lightweight aggregate in terms of density and compressive strength. The scoria falls within the moderate strength concrete with density and compressive strength of up to 1400 kg/m^3 and 14 N/mm^2 respectively.

Table 3: Spectrum of Lightweight Concrete (ACI 213)

	Lightweight Concrete Low strength	Moderate strength	Structural
Density (Kg/m^3)	250 500 750	1000 1250 1400	1500 1750 2000
Strength (N/mm^2)	0.7 - 2	(2 - 14)	(17-41)

Aggregates

Vermiculite
Perlite
Fly ash
Scoria
Expanded clay
Foarmed slag
Aerated concrete

CONCLUSIONS

Natural LWA are inert material that can be used as an alternative to normal weight aggregates for the production of LWAC toward sustainable infrastructural development. It can be deduced that:

- Lightweight concrete has proven to be a cost saving alternative in concrete construction since it contributes to the reduction in dead weight on supporting structures.
- Lightweight concrete of low density between 1000-2000kg/m^3could be produced as against normal concrete density of about 2400 kg/m^3.
- It is possible to produce high strength lightweight concrete by improving the interfacial bond between the aggregate and mortar or by using admixtures in the concrete composite production. Some of the additives that have yielded appreciable results are; silica fume, fly ash etc. but, more research efforts is required to determine the dosage of these additives and their suitability for use in different aggregate types.
- Compressive strength of up to 40 Mpa is achievable in lightweight concrete composite but only by the use of additives in the production process.

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