Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 2, Number 3; January-March, 2015 pp. 292-296

http://www.krishisanskriti.org/jceet.html

A Feasibility Study on Artificial Aggregates Using Waste Materials

V. Jagadish[1] and R. Jagadeesan[2]

[1]PG Student, K.S. Rangasamy College of Technology, Namakkal, Tamil Nadu
[2]Department Of Civil Engineering, K.S. Rangasamy College of Technology, Namakkal, Tamil Nadu
E-mail: [1]jagadishcivilrmk@gmail.com, [2]jagadeesan@ksrct.ac.in

Abstract—*This paper gives a review about on artificial aggregates made out of different waste materials like pond ash, fly ash, and steel slag...Etc. In our country the construction activity is increasing day by day. For that it requires the natural resources like sand, aggregate, etc. There is a demand for the natural resources like sand, aggregate. To overcome this demand we have to go for alternate sources. Using of Artificial aggregate in concrete is one of the techniques to solve the above problem. Artificial aggregate can be made out of these materials that are considered waste and pollutants of environment. For that manufacturing of artificial aggregates are adopted. Artificial aggregates are widely used for construction activity. Consequently, the manufacturing of artificial aggregates solves two problems, conserves environment from pollution and prevents natural resource from depletion. This report deals with manufacturing of artificial aggregates and its importance and also mainly throws light on the manufacturing process, properties and strength aspects and applicability of these categories of aggregates in civil engineering industry.*

1. INTRODUCTION

Reducing and recycling waste and by products have become the major issue in 21st century. Development of new techniques for managing wastes is one of the major areas of interest of researchers in recent days. This is due to the need for reusing the materials to avoid exhausting natural resources that are depleted abundantly with growing population. Due to the impact of earth quake forces all over the world, the need for light weight structural design is increasing presently, as it reduces mass of the structure. Light weight concrete also brings down the overall cost of the building. Light weight aggregates (LWA) are generally manufactured from pumice or volcanic cinders or clays or siliceous rocks. Natural aggregates are those that are taken from naturally occurring rocks by breaking and sieving them in to desired size. The usage of natural aggregates has become serious issue, due to the over use of these materials in this developing infrastructure era. Natural aggregates have density higher than that of light weight aggregates. Due to the low density of LWA, it provides better insulation property and can be used to produce light weight concrete. Light weight aggregate can also be produced using industrial by-products like heavy metal sludge, mining residues, palm shell, paper sludge, pet bottles, sewage sludge, steel slag, bottom ash, fly ash, marine clay etc.,

Here in this paper, some of the techniques that are used by the researchers to produce light weight aggregates from waste and by-products have been discussed briefly. There are numerous light weight aggregates available commercially which are obtained through expensive methods of manufacturing. Also, it depletes the natural resources for its raw materials. The best way to avoid this problem is to use the lightweight waste materials as raw material for aggregates in concrete. Beyond reducing the overall cost, this also finds a way to utilize this waste material that produce environmental problems.

Artificial aggregates made out of these waste products generally have different properties based on their source material, binder properties, method of manufacturing etc.,. The shape and texture of aggregate affects the fresh property of the concrete. Rounded aggregates endorse workability of concrete while the angular nature of natural gravel gives a better bonding property but requires more cement mortar for better workability. Well graded aggregate makes the cement paste consumption lesser, thereby reduces the cost of concrete. These can be achieved by reduced void ratio thereby reduces the amount of paste required to fill the voids. By using these large quantity of industrial wastes can be utilized for depletion of natural aggregates increase the various potential of manufacturing artificial aggregates from different waste including mining residues, heavy metal sludge, marine clay, palm shell, paper sludge, pet bottles, sewage sludge, steel slag, fly ash, bottom ash etc.,

Various methods are adopted for producing different artificial aggregates for fly ash aggregates which includes, sintering, autoclaving and cold bonding.etc

2. MATERIAL PROPERTIES

A materials used for manufacturing of artificial aggregates and its properties of the materials have been discussed below.

3. MATERIAL USED

CEMENT

Cement can be described as a material with adhesive and cohesive properties which make it capable of bonding mineral fragment into a compact whole and solid in the presence of water. Ordinary Portland cement was used in which the composition and properties is in compliance with the Nigerian standard organization defined standard of cement for concrete production .Ordinary Portland 43 grade cement with specific gravity 3.15 was used as the binder.

4. RICE HUSK ASH

Rice husk ash is produced by burning the outer shell of the paddy that comes out as a waste product during milling of rice. Since they are bulky disposal of husk present an enormous problem .Each ton of paddy produces about 200kg of husk and this rice husk can be effectively converted through controlled burning. At around 500ºC a valuable siliceous product that can enhance the durability of concrete in the chemical composition of rice husk ash is obtained. Variations in the burning temperature much above or below will drastically alter the silica content of the ash. It is estimated that one fifth of the five hundred million tons of world annual paddy production is available as rice husks. Only a small quantity of rice husk is used in agricultural field as a fertilizer, or as bedding etc. and stabilization of black cotton soils.

The manufacture and batching of Rice husk Ash involves bulk handling of a light raw material and proper and a controlled burning methodology has to be adopted. Grinding of the ash is done after necessary cooling and can be done to any desired fineness. The author manufactures RHA and adopts a fineness value of around 4200blaine.There is another difficulty in the manufacturing of RHA. Namely burning of the raw husk to a high temperature for a sustained period makes it extremely difficult to cool the ash to normal temperature. This is also compounded by the inherent nature of raw husk to retain heat for a considerably long time. Therefore the method adopted is to allow the burnt husk to stay for some time and subsequently cool with water. However, when this is done the Ash is saturated with moisture and therefore grinding becomes a challenging task-especially with an abrasive material like RHA. Therefore drying of RHA is a must. Among the several methods that are possible normal sun drying and / or drying using paddy driers are the cheapest options

5. APPLICATION OF RICE HUSK ASH

RHA has got numerous applications in silicon based industries. Substantial researches been carried out on the use of RHA as a mineral admixture in the manufacture of concrete. RHA in amorphous form can be used as a partial substitute for Portland cement and as an admixture in high strength and high performance concretes.

This product can be used many other applications like

- Green concrete
- High performance concrete
- Insecticides and bio fertilizers

Table 1: Properties of rice husk ash

`PROPERTY	RICE HUSK ASH
Sio2	86.98
Al2o3	0.84
Fe2o3	0.73
Na2o	0.11
K2o	2.46
CaO	1.40
MgO	0.57
Loss of ignition	5.14
PHYSICAL PROPERTIES	
Volumetric density (g/cm3)	2.10
Mean particle size (μm)	5

6. ADVANTAGES OF RICE HUSK ASH

The use of RHA in concrete has been associated with the following essential assets:

- Increased compressive and flexural strengths.
- Reduced permeability
- Increased resistance to chemical attack
- Increased durability
- Reduced effects of alkali-silica reactivity (ASR)
- Reduced shrinkage due to particle packing, making concrete denser
- Enhanced workability of concrete
- Reduced heat gain through the walls of buildings
- Reduced amount of super plasticizer

7. BOTTOM ASH

. Bottom ash from coal fired thermal power plants poses serious environmental problems due to disposal into ash ponds. Review reveals that bottom ash has been used as replacement of fine aggregate in concrete, pre-cast blocks, soil stabilization and in the formation of embankments. Bottom ash (BA) collected from a local coal-based thermal power station; having chemical composition similar to class-F fly ash was used. Bottom ashes have angular particles with a very porous surface texture. The ash is usually a well-graded material, although variations in particle size distribution may be encountered in ash samples taken from the same power plant at different times.

8. STEEL SLAG

Extraction of 'iron' from ores is a complex process requiring a number of other materials which are added as flux or catalysts. After making steel these ingredients forming a matrix are to be periodically cleaned up. Removed in bulk, it is known as steel –slag. It consists of silicates and oxides. Modern integrated steel plants produce steel through basic oxygen process. Some steel plants use electric arc furnace smelting to their size. In the case of former using oxygen process, lime (CaO) and dolomite (CaO. Mgo) are charged into the converter or furnace as flux.

The impurities are silicon, manganese, phosphorous, some liquid iron oxides and gases like CO_2 and CO. Combined with lime and dolomite, they form steel slag. At the end of the operation liquid steel is poured into a ladle. The remaining slag in the vessel is transferred to a separate slag pot. For industrial use, different grades of steel are required. With varying grades of steel produced, the resulting slag's also assume various characteristics and hence strength properties. Grades of steel are classified from high to medium and low depending on their carbon content. Higher grades of steel have higher carbon contents. Low carbon steel is made by use of greater volume of oxygen so that good amount carbon goes into combination with oxygen in producing CO_2 which escapes into atmosphere. This also necessitates use of higher amount of lime and dolomite.

The steel slag is used as aggregates. Natural aggregate resources are becoming more difficult to develop or remove aggregate from the ground when slag can be used as a substitute which reduce waste and conserve resources. It protects and preserves our environment. Benefit from technical advantages offered by many of the steel making slag's. High performance products not necessarily low grade applications

PROPERTIES OF STEEL SLAG

Steel slag aggregates are highly angular in shape and have rough surface texture. They have high bulk specific gravity and moderate water absorption (less than 3 percent). Table 3.4.1 lists some typical physical properties of steel slag.

Table 2: Physical properties of steel slag

PROPERTIES	VALUE
Specific gravity	3.2-3.6
Unit weight kg/m3	1600-1920
Absorption	Up to 3%

The chemical composition of slag is usually expressed in terms of simple oxides calculated from elemental analysis determined by x-ray fluorescence. Of more importance is the mineralogical form of the slag, which is highly dependent on the rate of slag cooling in the steel-making process.

Table 3: Chemical composition steel slags

CONSTITUENT	COMPOSITION (%)
CaO	40 – 52
SiO_2	10 – 19
FeO	10 – 40
MnO	5 – 8
MgO	5 – 10
Al_2O_3	1 – 3
P_2O_5	P_2O_5
S	< 0.1

9. ADVANTAGES IN STEEL SLAG

Heavier than most natural aggregate, Better Friction Asphalt Mixtures, Higher Stability (Less Rutting), Excellent Base Aggregate Due to Stability, High Angle of Internal Friction

10. FLY ASH

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata.

11. CHEMICAL COMPOSITIONAND CLASSICIFICATION

Because fly ash is a by-product material chemical constituents can vary considerably but all fly includes:

- Silicon Dioxide (SiO_2)
- Calcium Oxide (CaO) also known as(Lime)
- Iron (III) Oxide (FeO_2)
- Aluminum Oxide (Al_2O_3)

Depending on source coal may include on or more toxic chemicals in trace amounts like Arsenic, Beryllium, Boron, Cadmium, Chromium, Cobalt, Lead, Manganese, Mercury, Molybdenum, Selenium, Strontium, Thallium, and Vanadium

ASTM C618 Defines two classes of fly ash:

- Class C
- Class F

ASTM C618 requirements:

- Loss of Ignition (LOI) < 4%
- 75% of ash must have fineness of 45 µm or less

Primary difference between Class C and Class F fly ash is the amount of the amount of calcium, silica, alumina, and iron content in the ash

CLASS F FLY ASH

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementations' compounds.

12. CLASS C FLY ASH

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulphate (SO4) contents are generally higher in Class C fly ashes.

At least one US manufacturer has announced a fly ash brick containing up to 50% Class C fly ash bricks will reduce the embodied energy of masonry construction by up to 90%.

13. FLY ASH USES

- Portland Cement and Grout
- Flowable Fills (CLSM)
- Waste Stabilization and Solidification
- Raw Feed for Cement Clinkers
- Aggregate
- Asphaltic Concrete Mineral Filler
- Numerous Agricultural Applications

14. FINE AGGREGATES

River sand of size below than 4.75mm conforming to zone II of IS 383-1970 is used as fine aggregate. Laboratory tests were conducted for fine aggregate to determine its physical properties as per IS: 2386 part (III)

River sand is normally preferred over crushed sand since in the former particle shape is fully water worn by attrition which helps in reduction of water content of mix and also lesser resistance to pumping.

Table 4: properties of fine aggregates

Specific gravity	2.72
Fineness modulus	2.67
Bulk Density	1806 kg/m3
Water absorption	1.1%

15. ARTIFICIAL AGGREGATES: MANUFACTURING METHODS

AUTOCLAVING: This process involves addition of some chemical like cement, lime or gypsum in agglomeration stage. This induces bonding property in the material. The green pellets are then cured in pressurized saturated steam at a temperature of 1400C. This process helps in reducing bonding material in pellet formation and curing time (Bijen, 1986). But the strength and durability properties does not show much difference compared to normal curing.

COLD BONDING: It is the process of normal water curing at ordinary room temperature (Bijen, 1986). This process helps avoiding energy utilization as in case of other two methods. Niyazi Ugur Kockal et al. says that cold bonded aggregate shows poor properties compared to sintered aggregates But in contrary, Manikandan et al.says when curing time is increased, the aggregate properties are comparable with autoclaving and steam curing (Manikandan and Ramamurthy, 2008).

16. MANUFACTURING PROCEDURE

Artificial aggregates are manufactured by cold bonding process. The quarry dust, fly ash and cement are dry mixed in a pelletizer. The angle of rotation of the drum of the pelletizer is set as 25 degrees and speed of revolution is 26 rpm. The water is sprayed to the rotating drum containing dry mix.

17. PROPERTIES OF ARTIFICIAL AGGREGATES

Artificial aggregates made out of the waste products above generally have different properties based on their source material, binder properties, and method of manufacturing etc. The shape and texture of aggregate affects the fresh property of the concrete. Rounded aggregates promote workability of concrete while the angular nature of natural gravel gives a better bonding property but requires more cement mortar for better workability. Main application of artificial aggregates is for producing light weight concrete. This is because of the very low density of the source material. Paper sludge aggregate is used as masonry material and the replacement percentage is up to 10% (Ahmadi and Al-Khaja, 2001). Aggregate made from steel slag is considered for asphalt concrete and replaced for about65% (Maslehuddin et al., 2003). Palm shell aggregate has been replaced for 100% of coarse aggregate and it is used in structural application (Okpala et al., 1990;Mannan and Ganapathy, 2002; Payam Shafigh et al.,2011).One step ahead to it, bottom ash aggregate is suggested for high strength concrete and replaced for fine and coarse aggregate for replacement percentage of100% (Kim and Lee, 2010). Fly ash aggregates are widely used in many applications, mainly as lightweight aggregates in concrete.

18. CONCLUSIONS

Though, the properties of artificial aggregates mainly depend on its source material. But each of them has their specific application and usage in construction industry. The obtained aggregates can be considered for various applications like wall panels, masonry blocks, roof insulation material, structural load bearing elements etc., based on their obtained properties.

In this review understood that various processes involved in manufacturing of artificial aggregates provides a wide usages of available materials as an alternate for aggregates in concrete. There should be a greater importance on the development of new technology to manufacture artificial aggregates with minimum cost .Waste utilization in construction must be extensively taken up covering various aspects at different level to minimize the environmental pollution and growing cost of construction. This type of artificial aggregate also used in masonry blocks for high rise buildings, wall panels for multi-storey buildings, roof insulation material.etc. It’s quite alternate source of natural aggregates.

REFERENCES

[1] Fang-Chih Chang , Ming-Yu Lee , Shang-Lien Lo , Jyh-Dong Lin (2010)’Artificial aggregate made from waste stone sludge and waste silt’Journal of Environmental Management 91 (2010) 2289-2294

[2] Harilal B and Job Thomas(2013)’ Concrete made using cold bonded artificial aggregate’American Journal of Engineering Research (AJER) Volume-1 pp-20-25

[3] SaiyedFarhana,ParmarBhumika,PrajapatiJayesh,Prof. JayeshkumarPitroda (2013)‘A Study on Utilization Aspects of Stone Chips as an Aggregate Replacement in Concrete in Indian Context’International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue 8- August 2013

[4] Dembatapitiya.B,. Dissanayake3 W. D. S. H. PallewattaT. (2013)’ Calicut Tile Waste as an Alternative Coarse Aggregate for Lower Grade Concretes Journal of Engineering and Technologyof The Open University of Sri Lanka (JET-OUSL), Vol. 1, No.123-142

[5] Medina.c, Sánchez de Rojas.m.i, Frías.m(2012)Reuse of sanitary ceramic wastes as coarse aggregate in eco-efficient concretesCement & Concrete Composites 34 (2012) 48–54

[6] Claudio Ferone,Francesco Colangelo , Francesco Messina, Fabio Iucolano , Barbara Liguori and RaffaeleCioffi’(2013) Coal Combustion Wastes Reuse in Low Energy Artificial Aggregates Manufacturing‘ Materials 2013, 6, 5000-5015

[7] R. Cioffi , F. Colangelo F. Montagnaro , L. Santoro’ Manufacture of artificial aggregate using MSWI bottom ash’ Waste Management 31 (2011) 281–288

[8] Raffaelecioffi,ClaudioFreone, Franceco Messina ,Francesco Colngelo(2012)‘Artificial aggregate production from power plant solid waste by means of granulation process ‘ volume 2 232-239

[9] PayamShafigh , Hilmi Bin Mahmud, MohdZaminJumaat , MajidZargar’(2014) Agricultural wastes as aggregate in concrete mixturesConstruction and Building Materials 53 (2014) 110–117