DEVELOPMENT OF LIGHTWEIGHT AGGREGATES FOR MAKING STRUCTURAL CONCRETE USING PELLETIZATION METHOD AND BLENDED DRY MIXES OF HARD SHALE CLAY MATERIALS

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Abstract – This research paper covers innovative simple manufacturing process developed at the CWHR for making structural grade of lightweight aggregates using a semi automatic pelletizer or pellet mill equipment fabricated under the Public Sector Development Project of the CWHR with ID # 54 entitled: "***Exploration and Exploitation of Lightweight Aggregate along the Coast of Balochistan"***.

At the CWHR under an organized experimental programme simple pellitization method was established using production sequence for making pellets means rounded disc type shaped raw materials made by moistening with average of 18-20% water by weight of dry blended mixes of waste materials of hard shale clay with fine siliceous sands as expanding filler material.

At the CWHR a pellet mill was used for making pellets under principle of pelletization process and made pellets as raw blended feed materials prepared by blending of following 04 No. dry blended mixes for developing structural grade lightweight aggregate as per requirement of standard specification for lightweight aggregates for structural concrete ASTM C 330 (89):

1. Green shale clay and mud shale/soil of Karachi.
2. Manghopir shale clay and Karachi shale clay mixed with fine siliceous sand of Karachi.
3. Grey shale of district Lasbella Balochistan and mud shale clay of Hub.
4. Guwadar shale clay and fine green sand of coastal areas of Balochistan.

This paper gives an overall picture of lightweight aggregate prepared on lab. scale using rotary kiln for heating purpose.

The Authors discussed in details pelletization process for making lightweight aggregate after heating of pellets as raw feed materials at heating temperature 1150-1200oC for 30 minutes.

The test results stated in research report are to be regarded as substitute analytical research observation for using lightweight aggregate as lightweight building material for developing structural concrete with strength level 2500-3500 psi after 28 days.

Key Words: Lightweight Aggregate, Chemical Properties, Pelletization, Pelletizer, Shale, Clay, Rotary Kiln, Structural Lightweight Aggregate Concrete.

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3. All contingent staff

The economical aspects of using lightweight aggregate are also reviewed during laboratory investigation. Emphasis is placed on the fact that although the raw material is available for making lightweight aggregate but research trends are limited. Therefore the authors appreciated efforts of the following technical experts who are engaged in erection of large size industrial pilot plant for production of lightweight aggregate more than 10 tons per day at the CWHR.

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Introduction and General Overview

Before starting an experimental programme standard specification for developing structural grade lightweight aggregates for making structural concrete ASTM Designation: C330-89 was reviewed thoroughly and noted standard limits for developing structural grade lightweight aggregate were considered.

The ASTM C 330-89 covers following general characteristics viz. physical, chemical and mechanical properties with suitable test methods for estimation of durability and characteristics of structural lightweight aggregates:

i. Lightweight aggregates should be developed by using raw materials viz. clay, diatomite, shale, slate, mud shale etc. with expanding, pelletizing and direct thermal treatment method.

ii. Organic impurities, staining and loss on ignition should be determined before developing lightweight aggregates for structural concrete on large scale.

iii. Lightweight aggregate under physical properties / tests should meet with permissible limits given in the standard viz. %age of clay lumps and friable particles in aggregates, grading, unit mass, sampling, drying shrinkage and popouts test etc. [1]

An experimental study was conducted under an approved public sector development project of the CWHR to investigate the suitability of waste raw materials available along the coastal line of Balochistan as per scope of the project starting from Ghaddani coastal beach line to Guwadar including district Lasbella, (Winder and Hub regions) Balochistan and also in Karachi Manghopir area.

The pelletization is a simple manufacture method for developing lightweight aggregate after making pellets, a ball like shaped or square disc shaped raw feed materials in large quantity for heating at rotary kiln with required temperature.

The pelletization is a process for making pellets using waste materials of shale clay or hard shale stone with expanding fine ground fillers viz. diatomite, siliceous sand and other fine shale dust with required portion of water, which is later heated in the rotary kiln for making different categories of lightweight aggregates keeping in view of unit mass requirements.[2]

Lightweight aggregates are manufactured in developed countries with different brand names and manufacturing processes involved pelletization and direct thermal treatment method but pelletization is most economical based on usages of waste raw materials can be blended and moistened with water for making pellets and later on preparation of lightweight aggregates. [3]

The lightweight aggregate is a specialized and processed bloated material made of shale, clay, slate and other suitable minerallic aggregates. Mostly simple to highly advanced pulverizer is being used for making pellets.

The processed lightweight aggregate along with production methods were reviewed as per pelletization method thoroughly discussed in FIP manual of lightweight aggregate.

The survey data of the most important lightweight aggregate has been given with production method where pulverized raw materials have been used by suitable pelletizer. [4]

There has been very little use reported of the vast quantities of hard shale clay stones or

Shale mud waste stone existing at different mining and quarrying areas of district Lasbella Balochistan that can be used for making lightweight aggregate on pelletization method. In UK, USA, China, Germany, Iran and Russia different lightweight aggregate are made by pelletizing raw materials existing at mining and quarrying locations for making lightweight aggregate. [5]

At the coastal line of baluchistan a huge quanityt of diamaceous waste silica sand is available. The waste silica sand can be readily used in developing lightweight aggregate when mixed with fine and ground waste shale of stone dust materials. [6]

A study is also presented on the performance of reinforced concrete members made from locally available materials near construction sites. The suitable clay and shale is used for making lightweight aggregate with bulk density 55lb/ft3 and used in developing structural lightweight aggregate concrete with density 120lb/ft3 and cylinder compressive strength 2550psi. [7]

Typical thermal insulation materials using lightweight aggregate concrete made with lightweight aggregate using expanded clay, slate, shale and fine silica waste material commonly known as diamaceous silica sand on pelletization method from density of concrete range 513 to 1630kg/m3 . [8]

The pelletization method can be used for making different insulating lightweight concrete ranging from 100 to 800psi compressive strength with lightweight aggregate having dry unit weight 20lb/ft3 to 30 lb/ft3, another insultaing lightweight concrete with compressive strength 800 -2000psi using lightweight aggregate of dry unit weight of 40lb/ft3.

For structural purpose lightweight aggregate concrete with compressive strength 2500-3500psi lightweight aggregate concrete with dry unit weight 50-65lb/ft3 can be used. [9]

The objective of this study was to investigate the simple production process for making lightweight aggregate using pelletizer. The CWHR based on previous experiences and literature review following developments have been made:

i. Selection of raw materials
ii. Selection of simple pellet making unit for making lightweight aggregate.
iii. Use of waste materials for blending, pellet making and later on developing lightweight aggregate.

Experimental Programme

In this experiment raw materials were collected and processed by using pellet mill and following sequence were adopted:

i. At initial stage 04 No. batches of raw materials were used with materials ratio 1:1 (50:50%) by weight. The weight of each batch was 100 kg with 18 to 20% water. Following materials were used:
   a) Green shale clay and fine mud shale of Karachi
   b) Guwadar shale clay mixed with fine sand filler.
   c) Manghopir shale clay and fine sand of Karahi.
   d) Grey shale clay of district Lasbella Balochistan and Hub mud shale.

ii. Pelletization method: During laboratory work blended dry mix materials were used and the same was discharege batch wise through hopper and conveying to clay mixer where water was added for mixing.

iii. After mixing the material in clay mixer wet material was discharge in extruder for making pellets

iv. Preparation of lightweight aggregate: Pellets of 04 No. batches total 400kg was fired in rotary kiln with required temperature. Please see table 1.

TABLE 1.

Sample Number	Type of Lightweight aggregate and material	Bulk density lb/ft3	Water absorption (%)
A00	Structural lightweight aggregate with unit mass as per requirements of ASTM C330-89 Material: Grey shale + Hub mud shale – district Lasbella Balochistan	60-62	2.5
B00	Structural lightweight aggregate with unit mass as per requirements of ASTM C330-89 Material: Manghopir shale clay+ fine sand of Karachi.	55-57	2.7

Sample Number	Type of Lightweight aggregate and material	Bulk density lb/ft3	Water absorption (%)
C00	Structural lightweight aggregate with unit mass as per requirements of ASTM C330-89 Material: Guwadar shale clay fine green micaceous sand of coastal areas of Balochistan	63-65	2.8
D00	Structural insulating lightweight aggregate with unit mass as per requirements of ASTM C330-89 Material: Green shale clay+ mud soil of Karachi.	40-42	2.9

Visual Inspection and other test methods used

Standard specification ASTM C330-89 was reviewed for testing of 04 No. batches of lightweight aggregate, approximate weight 200kg (50kg each) for utilization of lightweight aggregate in structural concrete. Following general characteristics/ visual inspection and test methods were used viz. chemical compositions, physical properties and others were determined.

Lightweight aggregate as lightweight building materials for making structural lightweight concrete can be rejected if does not meet standard requirements. Grading requirements can be made when crushed lightweight aggregate developed based on pelletization method as per standard specifications. Please see table 2 &3.

TABLE 2.

Visual Inspected

Method of making	Organic impurities as per T 21	Staining	Loss on ignition
As per ASTM C330-89	Nil and extremely not found harmful to the structural concrete.	No strength therefore cannot be rejected. From batch no. 1 to 4 quantity of iron is above than 1.5mg/ 200g	Processed lightweight aggregate prepared at the CWHR are hydraulic in characteristic therefore loss on ignition is not exceed 5%

TABLE 3.

Clay lumps	Grading	Popouts test	Drying shrinkage
Not exceed 2% by dry mass	The grading confirm to the requirements.	Concrete specimen cubes of size 4" x4"x4" were casted with concrete mix ratio 1:2:4 at water ratio 0.65% , cured and autoclave the specimen in accordance with specification, visual inspected. No popouts established.	Not exceed from 0.07%

Discussion on Test Results

Lightweight aggregates from sample No. A to D are not contained excessive amount of deleterious substances and other harmful aggressive ionic media therefore can be suggested to use in structural concrete.

The physical, chemical and other properties are covered by the specification of ASTM C 330-89.

Lightweight aggregate prepared by processing natural materials, pelletizing and fired at rotary kiln with standard method of preparation.

Test methods and properties determined proved to use lightweight aggregate sample A to D in structural concrete. All tables are self explanatory therefore do not need further explanation.

Conclusion & Recommendations

The authors would like to thank the research team comprised of 05 No. technical experts were engaged in lab. investigation for making lightweight aggregate. The pelletizer/pellet mill fabricated by one of the local fabricator provided best results for making pellets. Rounded disc type pellets can be fired at suitable rotary kiln for developing lightweight aggregate.

The PSDP project of the CWHR can be supported if highlight the preliminary R&D results obtained by the CWHR. The CWHR is recommended to utilize structural grade LWA in concrete works.

Experimental Materials

Some efforts were used to collect raw materials from District Lasbella Balochistan and Karachi including grey shale clay available at wider coastal line of Balochistan (starting from Ghadani beach to Guwadar: 550k.m) with fine sand (diatomaceous/beach sand or dune sand) for making special blended dry mixes for developing pellets of lightweight aggregate. ***(See figure1 to 3)***

Figure 1. Beach/diatomaceous dune is an ideal filler for making pellets with grey shale clay of coastal areas of Balochistan

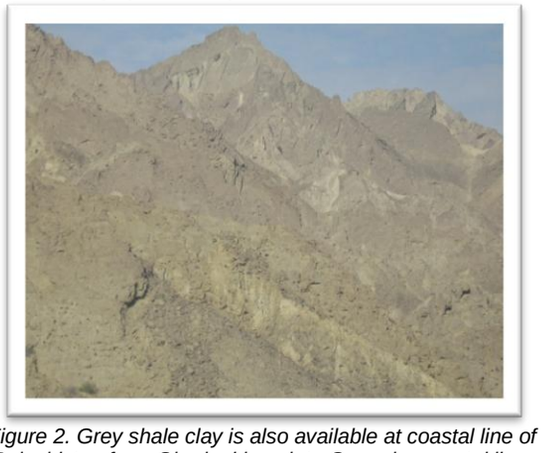

Figure 2. Grey shale clay is also available at coastal line of Balochistan from Ghadani beach to Guwadar coastal line.

Figure 3. Coastal fine beach sand of Ormara, Jivney and Guwadar beaches existing in billions of metric tons.

*The aim of this research study with detailed field survey conducted at coastal line of Balochistan was to evaluate the properties of waste materials of hard shale clay of district Lasbella Balochistan (Hub and Winder regions) and Manghopir Karachi where huge quantities of raw materials are available that can be used for making pellets as raw feed of making lightweight aggregate on rotary kiln process. (**See figure 4 to 7)***

After collection of raw materials typically designed pellets or blended raw materials were made using 02 blended mixes of shale clay and filler fine sand / clay for making lightweight aggregate.

Figure 4. Pellets are made by mixing of fine and ground green shale clay with mud shale of Manghopir Karachi

Figure 5. For making pellets, a circular disc type shape using fine and ground grey shale stone of district Lasbella Balochistan with mud shale of Karachi

R&D Works for making Structural Grade Lightweight Aggregate

On the pelletization method 04 categories of lightweight aggregates were developed using above raw materials. The pelletization is a process for making pellets rounded disc type or ball like shape on pellet mill or pelletizer by mixing wastes of hard shale stones existing at

shale mines/quarries and with mixing of fine expanding fillers coarser or very fine sands moistened with required portion of water which are later heated in rotary kiln at heating temperature 1150-1200oC for the period of 30 minutes for making lightweight aggregate.

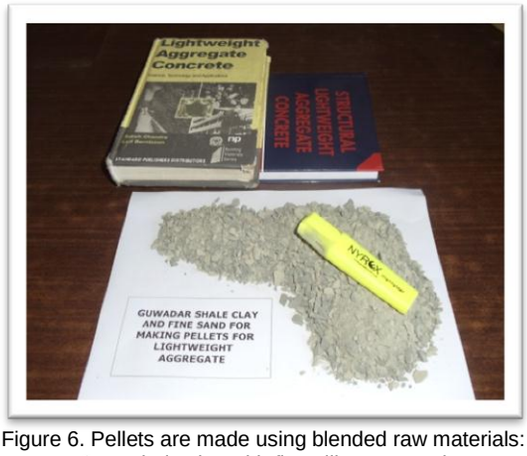

Figure 6. Pellets are made using blended raw materials: Grey shale clay with fine siliceous sand

Figure 7. These are Manghopir green shale and mud shale of Karachi used for making pellets of lightweight aggregate

At the CWHR pellets were made on locally fabricated pellet mill developed as semi automatic pellet making equipment under the project. Pellets were heated in lab. scale rotary kiln and made lightweight aggregate of structural grade by closely followed requirements of ASTM C 330-28a. **See figure 8 to 14**

Figure 8. Expanded lightweight aggregate are developed by using green shale clay of Manghopir mixed with fine mud/soil of Karachi

Figure 9. Expanded lightweight aggregate are developed by using Ghuwadar fine and ground grey shale clay mixed with fine dune green sand/ diatomaceous filler

Figure 10. Lightweight aggregate made from grey hard shale of district Lasbella (Winder) shale clay of Karachi

Figure 11. Expanded lightweight aggregate are developed by using Manghopir mud/ shale clay with fine sand of Karachi

Figure 12. Lightweight aggregate from green shale of Manghopir and mud clay shale of Karachi

Figure 13. Pellet mill is working to produce pellets for lightweight aggregate

Figure 14. Showing rounded shaped blended pellets are ready for making lightweight aggregate

Figure 15. A process of making pellets by pellet mill (semi automatic pelletizer) has been used.

Figure 16. A rounded disc type pellets made from blended mixes of shale clay and fine sand with optimum water requirements

TABLE 4.

Chemical Compositions of Un-bloated pellets materials tested for making lightweight aggregate

Name of Test	Karachi shale clay with fine sand	Ghuwadar grey shale clay with fine sand	Manghopir green shale clay with shale clay	Grey shale of Winder mix with green shale of Karachi
Silica	59.40%	54.76%	50.66%	51.10%
Alumina	11.60%	15.04%	19.35%	18.09%
Calcium Oxide as CaO	10.48%	10.42%	6.57%	7.17%
Magnesium Oxide as MgO	1.74%	1.78%	2.76%	2.18%
Sodium Oxide as Na_2O	0.30%	0.34%	0.29%	0.26%
Iron Oxide as Fe2O3	3.84%	3.14%	6.26%	7.49%
Potassium Oxide as K_2O	1.32%	1.27%	1.25%	1.46%
Loss on Ignition	11.07%	1268%	12.35%	11.69%
Sulfate as SO_4	0.002%	0.002%	0.002%	0.26%
Insoluble Residue	65.18%	60.34%	60.41%	59.75%

TABLE 5.

Chemical Compositions of bloated lightweight aggregate made by heating pellets as raw materials on rotary kiln process

Name of Test	Karachi shale clay with fine sand	Ghuwadar grey shale clay with fine sand	Manghopir green shale clay with shale clay	Grey shale of Winder mix with green shale of Karachi
Silica	56.95%	67.36%	66.56%	66.82%
Alumina	23.44%	11.01%	12.70%	11.14%
Calcium Oxide as CaO	5.64%	11.90%	11.49%	13.24%
Magnesium Oxide as MgO	2.52%	2.59%	1.96%	1.75%
Sodium Oxide as Na_2O	0.21%	0.24%	0.25%	0.20%
Iron Oxide as Fe2O3	9.60%	4.74%	5.08%	4.35%
Potassium Oxide as K_2O	1.34%	1.18%	1.26%	1.04%
Loss on Ignition	0.13%	0.46%	0.38%	0.41%
Sulfate as SO_4	0.002%	0.002%	0.002%	0.002%
Insoluble Residue	83.39%	84.61%	83.12%	84.79%

References

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