An Experimental Study on Manufacture of Artificial Aggregates Incorporating Flyash, Rice Husk Ash and Iron Ore Dust

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***Abstract* - The increasing demand for producing Durable Construction materials is the outcome of the fast polluting environment. Supplementary Cementitious materials prove to be effective to meet most of the requirements of durable concrete. Fly ash and Rice husk ash is found to be greater to other supplementary materials like silica fume. Due to its high Pozzolanic activity, both strength and durability of concrete are enriched.**

Artificial aggregates are made out of various waste materials. In the current scenario, the disposal problem of industrial by-products like Fly ash, Paper pulp, Municipal Solid waste, Power plant Solid waste, Saw dust, Rice husk ash, Granite powder Iron Ore Dust etc. On the other side, there is a demand on natural aggregates for the growing infrastructure industry, which creates problem of depleting Natural resources and hence a need for Artificial aggregates. The world is much interested in innovative production of alternate material in construction industry recently using industrial byproducts, the large scale utilization of these industrial by products reduces environmental pollution and dwindling of natural resources. Hence there is a need for, the production of artificial aggregates, which meets present requirement of the construction industry.

In the present project on artificial aggregate Manufactured incorporate Fly ash , Rice husk ash and Iron ore dust aggregate are mixed together with cement can produce an artificial aggregate. The Evaluation of Mechanical properties like Compressive strength, Weight loss and Reduction in Strength was monitored up to 56 days and Durability test was conducted on normal cured specimens, for 28 days continuous immersion in Nacl Solution. From the results, it shows that the present manufactured aggregates.

***Keywords*- Artificial Aggregates, Fly Ash, Rice Husk Ash, Iron Ore Dust, Compressive strength & Durability test.**

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I. INTRODUCTION

Aggregate is a collective term for the mineral materials such as sand, gravel and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as asphalt concrete and Portland cement concrete). Aggregate is also used or base and sub base courses for both flexible and rigid pavements.

Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often the byproduct of other manufacturing industries. Byproduct aggregates such as blast-furnace slag and cinders or manufactured aggregates such as lightweight aggregates including expanded clay or shale, processed diatomaceous earth, processed volcanic glasses, and expanded slag (McLaughlin and others, 1960) are called Artificial aggregates.

II. NEED OF ARTIFICIAL AGGREGATES

In the present scenario, construction industry is growing very fast manner. The availability of raw materials for the construction is facing many problems in most of all countries. The disposal problem of industrial by-products like fly ash, paper pulp, heavy metal sludge, marine clay, palm shell, paper sludge, pet bottles, sewage sludge, steel slag, bottom ash etc., The continuous usage of natural resources for the production of the concrete in some locations create many threatens to the environmental conditions. Researchers have carried out extensive work on this area are trying for new alternative materials for this deficiency in the construction industry. In this condition, the present study on artificial coarse aggregate has much importance. The coarse aggregates from waste materials like fly ash, Rice Husk ash and Iron Ore Dust with cement as binder can be used in concrete. On the other side, shortage of natural aggregates in the growing infrastructure industry, creates problem of depleting natural resources which builds the need for artificial aggregates. The mainly throws light on the manufacturing process, properties and strength aspects and applicability of these categories of aggregates in civil engineering industry. The artificial aggregate can be produced without affecting the natural sources. Hence it is ecofriendly material. So the artificial aggregate is used in concrete.

III. NEED OF THE RESEARCH

The stones are derived from rocks which form the earth‘s crust and have no definite shape or chemical composition but are the mixtures of two or more minerals. The stones form the important coarse aggregate in concrete. The place from which the stone is obtained (by digging or blasting) is known as Quarry‘. The quarry site generally adopts blasting instead of digging since blasting is fast process when compared to digging. The blasting method is very dangerous to live hood and earth structure. While blasting it is found the ground surface were induced by certain vibrations and seismic intrusions which warily affects the tectonic plate division. The changes in tectonic boundaries sometimes causes the

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region more prone to earthquake so the government have enacted a law, if the area is more prone to earthquake the excavations of natural resources should be prohibited in that area. This was the reason today the world suffers from aggregate scarcity.

The researcher inspired a new concept called artificial aggregates in order to avoid aggregates scarcity for the present world. The artificial aggregate are mainly manufactured from the by-products like rice hush ash, fly ash, steel slag, paper sludge, solid wastes, etc. This eco-friendly material does affect the environment at any case and does not incorporate any chemicals. Because of its ecofriendly nature today it found great place in concrete technology.

IV. OBJECTIVE

- To produce Eco-Friendly concrete using Artificial Aggregates.
- To study the Physical & Mechanical properties of Artificial Aggregates.
- To compare the Compressive Strength of Concrete Incorporated with Artificial Aggregates and Conventional Concrete.

V. SCOPE OF THE PROJECT

- To procure Industrial waste materials namely Flyash, Rice Husk ash and Iron Ore Dust.
- To study the physical, mechanical properties of Natural and Artificial aggregate.
- The preliminary tests are Specific gravity, Water absorption and Sieve analysis of coarse and fine aggregate.
- To find the compressive strength of artificial aggregate concrete and compare it with compare to conventional concrete.
- To test the durability of artificial aggregate concrete.
- To manufacture the Artificial Aggregates.

VII. PREVIOUS STUDY

Fly ash is an industrial waste and a material of puzzolanic characteristic occurring due to burning the pulverized coal in the thermal power plants. **(ACI Committee 1987; Erdo˘gan 1997).** The fly ash, similar to other pozzolans, affects the technical properties of the concretes and mortars by its pozzolanic characteristics and filler effect. It is known that the filler effect of the fly ash is more effective than the pozzolanic characteristics when affecting the properties of concrete **(Goldman & Bentur 1993; Aiqin et al 2003).**

The fly ashes contain surplus amount of silica, alumina and iron oxide; they have a structure with very fine particles and amorphous. Materials with silica and alumina in the structure of fly ashes make additional calcium silicate hydrate (C-S-H) by reacting with calcium hydroxide occurring as a consequence of hydration of the cement. The resultant C-S-H gels cause increase in strength of the concrete. Very fine particle increases compactness in the concretes or mortar and causes filling of the spaces. Using the fly ash in the concrete generally increases the workability of the fresh concrete, decreases the bleeding, decreases the hydration temperature, decreases the permeability of the hardened concrete, increases resistance of the concrete to the chemical effects, and decreases the costs **(ACI Committee 1987; Erdo˘gan 1997; Chindaprasirt et al 2005; Toutanji et al 2004).**

Strength of the concretes in which fly ash is used instead of up to 30% of the cement is lowerthan Portland cement concretes at the early stages but the ultimate strength in the later year is higher. The increase in the strength of the concrete with fly ash changes depending on the fineness, type and usage ratio of the fly ash and the cement type. The contribution of the type C ashes to the strength in the earlier times is higher than the type F ashes **(Erdo˘gan 1997; Malhotra 1995; Toutanji et al 2004).**Increasing fineness of the fly ash also increases its puzzolanic activity and density. As a result of this, strength and durability of the concretes containing fly ash are affected positively **(Erdo˘gan 1997; Jaturapitakkul et al 1999; Kiattikomol et al 2001).**The coarse fly ash was ground and obtained fly ashes which had particles between 1.9 and 17.2 micron **(Kiattikomol *et al* 2001).**

P. Priyadharshini., et.al (2012) - A Review on Artificial Aggregates‖ made out of various waste materials. In the current scenario, the disposal problem of industrial by-products like fly ash, paper pulp, heavy metal sludge, marine clay, palm shell, paper sludge, pet bottles, sewage sludge, steel slag, bottom ash etc., has become an environmental issue due to the pollution caused. Artificial aggregate can be made out of these materials that are considered waste and pollutants of environment. On the other side, shortage of natural aggregates in the growing infrastructure industry, creates problem of depleting natural resources which builds the need for artificial aggregates. This paper mainly throws light on the manufacturing process, properties and strength aspects and applicability of these categories of aggregates in civil engineering industry. Consequently, the production of artificial aggregates solves two problems, conserves environment from pollution and prevents natural resource from depletion, thereby giving way to sustainable development.

A.Siva Kumar., et.al-(2011) - Pelletized fly ash lightweight aggregate concrete: Crushed aggregates are commonly used in concrete which can be depleting the natural resources and necessitates an alternative building material. Fly ash is one promising material which can be used as both supplementary cementitious materials as well as to produce light weight aggregate. The use of cost effective construction materials has accelerated in recent times due to the increase in the demand of light weight concrete for mass applications. This necessitates the complete replacement or partial replacement of concrete constituents to bring down the escalating construction costs. In recent times, the addition of artificial aggregates has shown a reasonable cut down in the construction costs and had gained good attention due to quality on par with conventional aggregates. The cost effective and simplified production techniques for manufacturing fly ash aggregate can lead to mass production and can be an ideal substitute for the utilization in many infrastructural projects.

J. M. J. M. Bijen., et.al, (2011) - Manufacturing processes of artificial lightweight aggregates from fly ash‖. Agglomeration techniques and hardening methods are described here. A division is made according to the method of

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hardening: sintering, autoclaving or cold bonding. It is concluded that sequence the bond between the fly ash particles in general diminishes; this effect, however, can be compensated by improving the degree of compaction of the green aggregates. Sintering processes can accept fly ash with fairly high carbon contents, whilst the other processes prefer low carbon fly ashes.

Fang-Chih Chang., et.al, (2010) - Artificial aggregate made from waste stone sludge and waste silt‖. Waste stone sludge obtained from slab stone processing and waste silt from aggregate washing plants were recycled to manufacture artificial aggregate. Fine-powdered stone sludge was mixed with waste silt of larger particle size; vibratory compaction was applied for good water permeability, resulting in a smaller amount of solidifying agent being used. For the densified packing, the mix proportion of waste stone sludge to waste silt was 35:50, which produced artificial aggregate of more compact structure with water absorption rate below 0.1%. In addition, applying vibratory compaction of 33.3 Hz to the artificial aggregate and curing for 28 days doubled the compressive strength to above 29.4 MPa. Hence, recycling of waste stone sludge and waste silt for the production of artificial aggregate not only offers a feasible substitute for sand and stone, but also an ecological alternative to waste management of sludge and silt.

Raffaele Cioffi., et.al, (2010) - The wastes of weathered coal fly ash (CFA), a wastewater treatment sludge (WTS) and a desulphurization device sludge (DDS) and they were coming from an ENEL (Italian Electricity Board) power plant were used to artificial aggregate. Broken waste content was from 60 to 90%. Hydraulic lime (L) was added as commercial binder. The three different systems were based on CFA-L, CFA-L-WTS and CFA-L-WTSDDS mixtures, respectively. The granules obtained were tested to assess their density, water adsorption capacity, compressive (crushing) strength and leaching behavior. Concrete mixes have been prepared and successfully tested from the technological point of view, proving to be suitable for the manufacture of classified concrete blocks.

S. S. Arilewola., et.al, (2011**)** - To find the effect of aggregate size on physical and mechanical propertied of concrete. Four categories of coarse aggregates sizes were considered: sample A (those that passed through 20mm sieve but retained on 14mm sieve), sample B(those that passed through 14mm but retained on 10mm sieve), sample C(combination of 50% of Sample A + 50% of sample B) and sample D(65% of sample A + 35% of sample B). Mix of 1:2:4 was prepared (coarse aggregates, sharp sand as fine aggregates, and Ordinary Portland Cement as binder) and water cement ratio of 0.5. Concret cubes from sample C (50% of A + 50% of B) gave the highest compressive strength (25.25 N/mm2) and concrete prepared using sample C aggregates absorbed least water and had a percentage saturation of 2.340%. Also, concrete cubes from sample A (P20R14) had the least strength (24.27N/mm2) and concrete from sample A absorbed more water with percentage saturation of 3.249%.

González-Corrochano., et.al, (2012) - To wash aggregate sludge and fly ash, raw material used to produce L.W.As, optimized BCR sequenced extraction applied. Result, it has been possible to evaluate the effects of the heating process on the extraction behavior of twenty-eight elements. The thermal process reduces the availability of all the studied heavy metals, with the exception of Mo. The availability of the other elements is also reduced, with the exceptions of As and Sb, which increase in the non-residual fractions.

Satoshi Kimura., et.al, (2004) - Fine-grade artificial lightweight aggregate particles (particles diameter 300–600 μm) were successfully manufactured by using a fluidized bed with spherical mullite particles for inert bed materials. Fluidized bed products had a smooth external surface and uniformly dispersed bubbly structure and showed low water absorption than a rotary kiln test product ALAs by adjusting the sintering condition, e.g., 911 to 1520 kg/ m3. The tensile strength and isotactic compressive strength were proportional to its apparent density. The fluidized bed products showed higher resistance to mercury intrusion than the rotary kiln product satisfying the requirements of strength to produce precast siding boards by high-pressure extrusion casting. These indicate the potential of fluidizedbed processes for manufacturing high performance fine-grade artificial lightweight aggregates.

Ivanka Netinger., et.al, (2013) - Electric arc furnace (EAF) steel slag as byproducts from the steel production industry is considered as an aggregate which could improve post-fire properties of concrete due to the fact that it is the material that is made at the temperatures of up to 1650 °C. Five high-strength concrete (HSC) mixtures were prepared: reference mixture with dolomite aggregate and four concrete mixtures with two types of steel slags available from Croatian steel plants as a coarse aggregate. Two slag based concrete mixtures were prepared with the slags that were previously thermally treated. At the age of 56 days concrete specimens have been exposed to high temperatures up to 800°C. Upon cooling of the specimens their residual properties (compressive strength, modulus of elasticity, weight loss and ultrasonic pulse velocity) were tested and compared with the same properties of the reference concrete. The impact of each individual component of concrete mixtures on the behaviour of concrete under high temperatures the dilatometer analysis of cement paste and all aggregate types used in studied mixtures was conducted. The obtained results showed that slag could improve fire performance of concrete in the temperature range up to 400°C.

J. L. van der Wegen., et.al, (2013) - Tthe mechanical properties and durability of the coarse aggregates investigated decrease in the sequence river gravel, Lytag, Aardelite and Niro Atomizer, which appears to be related to the type of bonding within the coarse aggregate particles. The properties of concrete produced from these artificial aggregates and river sand having an average 28 day compressive strength of about 30 MPa are also reported. Concrete mixes having about similar workability and average 28 day compressive strength show that the required free water content is 4% and 9% less for Lytag and Aardelite concrete respectively compared to the gravel concrete. The features of the artificial aggregates are compared with those of the common Dutch coarse aggregate river gravel.

Peter Neumann., et.al, (2012) - A technology has been developed to convert combustion ashes into concrete

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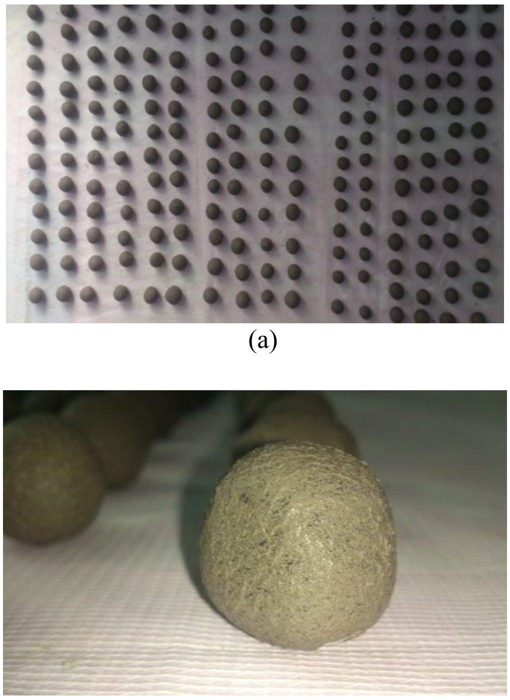
aggregate by high pressure agglomeration of ash port land clinker blends and subsequent curing. The obtained product may be employed in ordinary concrete manufacturing and even yields higher strength due to an improved aggregate-cement paste bonding.

Alonso-Azca rate., et.al, (2009) - Washing aggregate sludge from a gravel pit, sewage sludge from a wastewater treatment plant (WWTP) and a clay-rich sediment have been physically, chemically and mineralogically characterized. They were mixed, milled and formed into pellets, pre-heated for 5 min and sintered in a rotary kiln at 1150°C, 1175°C, 1200°C and 1225°C for 10 and 15 min at each temperature. The mixtures presented a bloating potential taking into consideration the gases released at high temperatures. The products obtained were lightweight aggregates (LWAs) in accordance with Standard UNE-EN- 13055-1 (rb 1.20 g/cm3 or particle density 2.00 g/cm3). LWAs manufactured with 50% washing aggregate sludge and 50% clay-rich sediment were expanded LWAs (BI > 0) and showed the lowest apparent particle density, the lowest water a absorption and the highest compressive strength.

VII. EXPERIMENTAL DESIGN

The artificial aggregates are manufactured by natural materials like fly-ash, rice hush ash, steel slag, paper sludge, solid wastes etc. The fly ash is the residue from the combustion of pulverized coal collected by the mechanical or electrostatic separators from the flue gases of the thermal power plants. The fly-ash obtained from the electrostatic precipitators is finer than the Portland cement, whereas that obtained from cyclone separators is comparatively coarser and may contain large amount of sunburnt fuel. It consists of spherical glassy particles ranging from 1 to 150 µm in diameter of which the bulk passes through a 45 µm sieve. The fly-ash like Portland cement contains oxide of calcium, aluminum and silicon but the amount of calcium oxide is considerably less. Rice husk is the by-product obtained from the milling of rice. This husk contains 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA).

This RHA in turn contains around 85 % - 90 % amorphous silica. So for every 1000 kgs of paddy milled, about 220 kgs (22 %) of husk is produced, and when this husk is burnt in the boiler, about 55 kgs (25 %) of RHA is generated. The particle size of the RHA is less than 35 µm because of this property it forms major strength and density of the aggregate. Iron ore is the waste material which is obtained from the lathe industry. These iron ore are hard solid by- product they are crushed together to make it powder form. The iron ore are incorporated in order to increase the density. The composition of iron ore constitute major portion of iron and oxides. In manufacturing of artificial aggregates the fly-ash, RHA and iron ore are found to be the major ingredients. About 40 % of flyash, 40% of iron ore, 10% RHA and 10 % binder. The sequence of the manufacture of the Coarse Aggregate by using Rice husk ash, flyash, and Iron ore dust in shown in fig 7.1



(a)

(b)

Figure 7.1 Stages in the manufacture of the Coarse Aggregate

Here the binder is the ordinary Portland cement. In general fly-ash, RHA and iron ore does not contain any binding agent to form tight aggregate the addition of cement is employed. The portable water is added to make them uniform homogenous mix.

The 1 kg of the cementious mixture requires 250 ml of portal water to mix to form homogenous mixture i.e. 400 g fly-ash, 400g iron ore, 100 g RHA and 100g cement requires 250 ml of water to blend well. The portable water is supplied by Dr.S.J.S. Paul Memorial College for this artificial aggregate manufacturing process. Since here the manufacturing process is carried by man-made method the cementious are obtained for 1kg for the moment. Due to setting property of cement and the manufacturing of aggregates is slow since it is man-made the artificial aggregates are made per hour 1 kg. The shape of the aggregate should be rounded and does not contain any voids during its manufactured it should well compacted by hand itself. the aggregates are cured for 24 hours in air and water curing is done from day 2 to minimum 28 days or maximum as we require. As the curing days increases the strength of the aggregates will also increases. The capacity of concrete to resist deterioration from freezing and thawing, heating and cooling, the action of chemicals such as deicers and fertilizers, abrasion, or any other environmental exposure will determine its service life.

The durability test of the control mix as well as the artificial aggregate concrete mixes tested after immersion in 5% NaCl solution for 28 days .The above specimen are cured in normal water initially for 28 days and then cured in NaCl solution for 28 days. The result of the test on compressive strength is tabulated as below.

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Table 7.1 Compressive Strength of Concrete using Artificial aggregates at various ages of Curing

S.NO	Type of Concrete Mix	Compressive Strength @ Various Ages (N/mm^2)			
		@ 7days	@14 days	@28days	@ 56days
1.	Reference mix	15.96	19.93	25.86	31.56
2.	Artificial Aggregate Concrete	8.22	11.04	18.07	22.96

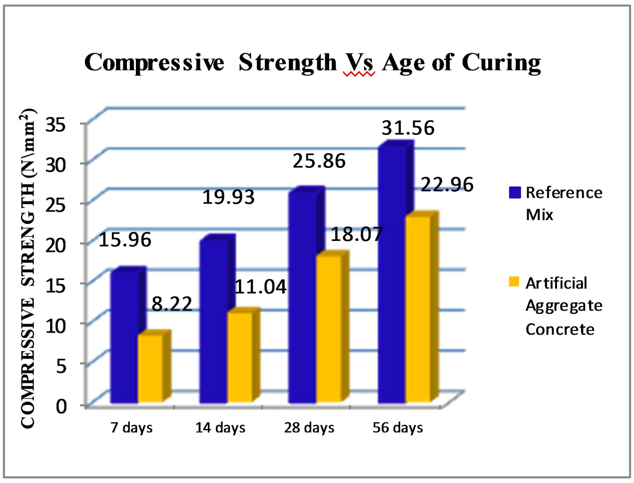

Fig 7.2 Compressive Strength Vs Age of Curing

Table 7.2 The Variation of Compressive strength after this durability test in NaCl solution is shown in

SL NO	Type of Concrete mix	Compressive Strength (N/mm^2)	
		Before Durability Test	After Durability Test
1	Reference mix	**25.86**	**19.55**
2	Artificial Aggregate Concrete	**18.07**	**11.40**

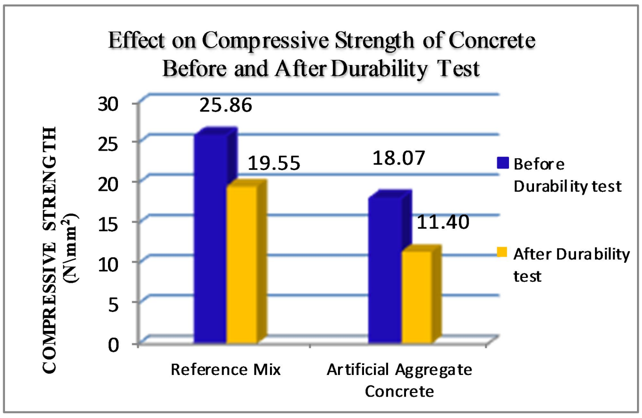

Figure 7.3 Effects on Compressive Strength of Concrete Before and After Durability Test

VIII. CONCLUSIONS

Based on the present study, the following are conclusions

- As a pilot study, Artificial aggregates has been prepared man made and cold bonding technique and the property of the obtained aggregates has been compared with natural gravel and results are found to be comparable.
- The rounded shape of artificial aggregate gives better workability compared to the angular natural gravel.
- Crushing and impact value shows value much lesser than the allowable limit. Abrasion value is too low but still cannot be used as a high way material due to its high percentage of water absorption. Though both natural and artificial aggregates shows crushing and impact value within the limit of 45%, Artificial aggregate shows 31.8% lower value than the natural aggregate for crushing and 26.4% higher impact value. But abrasion nearly equal for both cases.
- Low specific gravity compared to natural gravel proves it to be a light weight aggregate material and artificial aggregate has been consumed in large volume when it is used as a coarse aggregate replacement material due to its occupation of large volume in concrete. This in turn reduces the problem of dumping as landfills to greater extent.
- The water absorption of artificial aggregate is 9 times higher than that of natural gravel which is the major disadvantage which can be eliminated by various treatment methods that are available like treating with water-glass etc.,
- Concrete with density 2151 kg/m3 can be achieved using artificial aggregates while density of normal concrete mix goes up to 2498 kg/m3.
- Though compressive strength of Artificial Aggregate concrete is 30 % lesser compared to normal concrete mix, it exceeds the value of 20MPa that has been fixed as minimum criteria for concrete to be used as a structural material.
- Cost effective construction practices with alternate construction materials are most desired in terms of huge savings in construction cost.
- Since, Artificial aggregates shows results comparable with natural gravel and the natural resource is in the side of depletion, artificial aggregates can be considered as a replacement material for coarse aggregate. Also, it improves the property of concrete as Artificial aggregates is a pozzolanic material. The obtained aggregates can be considered for various applications like wall panels, masonry blocks, roof insulation material, structural load bearing elements etc.,
- From the durability studies the compressive strength was 42% less than the reference mixes, and also the penetration of chloride ions present in both Reference and Artificial aggregate concrete.

References

[1] M.S. Shetty for Concrete Technology, Theory and practice book 2012.

[2] P. Priyadharshiny, G.M. Ganesh and A.S. Santhi, Experimental study on cold bonded fly ash aggregates, *International journal of Civil and Structural engineering,* **(2), 2011. 10506-1062.**

[3] L.A. Bui, C.I. Hwang, C. Chen, K. Lin and M. Hsieh, Manufacture and performance of cold bonded lightweight aggregate using alkaline activators for high performance concrete, Construction and Building Materials, (35), 2012, 1056-1062.

ISSN: 2278 – 7798

[4] Brock, C:W., 1983, "Some Aspects of Sinter Quality ", A max Iron ore Corporation, Australia.

[5] Murashige, T.: The impact of plant tissue culture on agriculture, p. 15-26. In Thorpe, T. (ed.), Frontiers of plant tissue culture. The International Association of Plant Tissue Culture, Calgary (1987).

[6] Redenbaugh, K., Paasch, B. D., Nichol, J. W., Kossler, M. E., Viss, P.R., and Walker, K. A.: Somatic seeds: encapsulation of asexual plant embryos. Bio/Technol., 4, 797-801 (1986).

[7] Uozumi, N., Nakashimada, Y., Kato, Y., and Kobayashi, T.: Production of artificial see from horseradish hairy root. J. Ferment. Bioeng., 74, 21-26 (1992).

[8] Repunte, V. P., Kino-oka, M., Taya, M., and Tone, S.: Reversible morphology change of horseradish hairy roots cultivated in phytohormone-containing media. J. Ferment. Bioeng., 75, 271-275 (1993).

[9] Noda, T., Tanaka, N., Mano, Y., Nabeshima, S,, Ohkawa, H., and Matsui, C.: Regeneration of horseradish hairy roots incited by Agrobacterium rhizogenes infection. Plant Cell Rep., 6, 283-286 (1987).

[10] Murashige, T. and Skoog, F.: A revised medium for rapid growth and bioassays with tobacco tissue culture. Physiol. Plant., 15, 473-497 (1962).

[11] Repunte, V. P., Shimamura, S., Taya, M., and Tone, S.: Characteristics and growth kinetics of adventitious roots emerging out of cell aggregates derived from horseradish hairy roots. J. Chem. Eng. Japan, 27, 523- 528 (1994).

[12] Naylor, A. W.: Functions of hormones at the organ level of organization, p. 172- 218. In Scott, T. K. (ed.), Hormone regulation of development, II. Springer-Verlag, Berlin, Heidelberg (1984).

[13] Fujii, J. A. A., Slade, D. T., Redenbaugh, K., and Walker, K. A.: Artificial seeds for plant propagation Bio/Technol., 5, 335-339 (1987).

[14] Redenbaugh, K., Slade, D., Viss, P., and Fujii, J. A.: Encapsulation of somatic embryos in synthetic seed coats. Hort. Science, 22, 803-809 (1987).

[15] Gee, G.W., Bauder, J.W., 1986. Particle size analysis. In: Klute, A. (Ed.), Methods of Soil Analysis: Part 1. Agronomy Handbook, No 9. American Society of Agronomy and Soil Science Society of America, Madison, WI, pp. 383–411.

[16] Guisan, A., Edwards, T.C., Hastie, T., 2002. Generalized linear and generalized additive models in studies of species distributions: setting the scene. Ecological Modelling 157, 89–100.

[17] Hastie, T.J., Tibshirani, R.J., 1990. Generalized Additive Models. Chapman and Hall.

[18] Huading, S., Jiyuan, L., Dafang, Z., Yunfeng, H., 2007. Using the RBFN model and GIS technique to assess wind erosion hazard of Inner Mongolia, China. Land Degradation and Development 18, 413–422.

[19] Huang, Y., Lan, Y., Thomson, S.J., Fang, A., Hoffmann, W.C., Lacey, R.E., 2010. Development of soft computing and applications in agricultural and biological engineering.Computers and Electronics in Agriculture 71, 107–127.

[20] Indian Space Applications Centre (ISRO), 2002. Data Products Software Division. Signal and Image Processing Group, SAC/ISRO, Ahmadabad-380 015, Government of India.

[21] Iranian Geological Organization, 2006. Geological Survey of Iran. Shahrekord, Iran.

[22] Jang, J.S.R., Sun, C.T., 1995. Neuro-fuzzy modelling and control. Process IEEE 83, 378–406.

[23] Juang, C.H., Chen, C.J., Tien, Y.M., 1999. Appraising CPT-based liquefaction resistance evaluation methods-artificial neural network approach. Canadian Geotechnical Journal 36, 443–454.

[24] Kemper, W.D., Rosenau, K., 1986. Size distribution of aggregates. In: Klute, A. (Ed.), Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods. American Society of Agronomy, Madison, WI, pp. 425–442.

[25] Kirkby, M.J., Morgan, R.P.C., 1980. Soil Erosion. John Wiley & Sons, New York (312 pp.)

[26] Kisi, O., Haktanir, T., Ardiclioglu, M., Ozturk, O., Yalcin, E., Uludag, S., 2009. Adaptive neuro-fuzzy computing technique for suspended sediment estimation. Advances in Engineering Software 40, 438– 444.

[27] Le Bissonnais, Y., 1996. Aggregate stability and assessment of soil crustability and erodibility: I. Theory and methodology. European Journal of Soil Science 47, 425– 437.

[28] Mashrei, M.A., Abdulrazzaq, N., Abdalla, T.Y., Rahman, M.S., 2010. Neural networks model and adaptive neuro-fuzzy inference system for predicting the moment capacity of ferrocement members. Engineering Structures 32, 1723–1734.

[29] McCullagh, P., Nelder, J.A., 1989. Generalized Linear Models, 2nd ed. Chapman and Hall, London.

[30] Nelson, D.W., Sommers, L.P., 1986. Total carbon, organic carbon and organic matter. In: Page, A.L. (Ed.), Methods of Soil Analysis: Part 2: Agronomy Handbook No 9. American Society of Agronomy and Soil Science Society of America, Madison, WI,pp. 539–579.

[31] Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K., Yoder, D.C., 1997. Predicting oil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). Agriculture Handbook, vol. 703. U.S. Department of Agriculture.

[32] Saridemir, M., 2009. Predicting the compressive strength of mortars containing metakaolin by artificial neural networks and fuzzy logic. Advances in Engineering Software 40, 920–927.

[33] ASTM-C 618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

[34] Chi, JAM, R. Huang, C.C. Yang and J.J. Chang, Effect of aggregate properties on the strength and stiffness of lightweight concrete .Cement & Concrete Composites, (25), 2003,197-205.

[35] M. Gesoglu, T. Ozturan, and E. Gooneys, Shrinkage cracking of light weight concrete made with cold –bonded fly ash aggregate. Cement and Concrete Research, (34), 2004, 1121-1130.

[36] B.W. Jo, S.K. Park and J.B. Park, Properties of Concrete Made with Alkali Activated Fly Ash Lightweight Aggregate, Cement & Concrete Composites, (29), 2007, 33-38.

[37] G. Joseph and K. Ramamurthy, Effect of cold bonded aggregate on workability and mechanical properties of Concrete. Inst. Of Engineers J. (India), (89), 2008, 33-38.

[38] G. Joseph,K. and Ramamurthy, Influence of fly ash on strength and sorption Characteristics of cold-Bonded Fly ash Aggregate Concrete, Construction and Building Materials, (23), 2009, 1862-1870.

[39] G. Joseph and K. Ramamurthy, Autogenous Curing of Cold –Bonded Fly – Ash –Aggregate Concrete. Journal of Materials in Civil Engineering, (23), 2011,393-401.

[40] M. Gesoglu, E. Gooneys and H.O. Oz, Properties of light weight aggregate produced with cold –bonding pellatization of fly ash and ground granulated blast furnace slag. Material and Structures, (45), 2012, 1535- 1546.

[41] L.A. Bui, C.I. Hwang, C. Chen, K. Lin and M. Hsieh, Manufacture and performance of cold bonded lightweight aggregate using alkaline activators for high performance concrete, Construction and Building Materials, (35), 2012, 1056-1062.

[42] IS:10262, Concrete mix proportioning - Guidelines, Bureau of Indian Standards, NewDelhi, 2009.

[43] P. Priyadharshiny, G.M. Ganesh and A.S. Santhi, Experimental study on cold bonded fly ash aggregates, International journal of Civil and Structural engineering, (2), 2011, 493-501.

[44] Bijen, J. M.J.M.'Flyashaggregates', Intron Report No. 83236, Maastricht, Netherlands,1983, pp. 21-63.

[45] Harrison, W. H. and Munday, R. S. 'An investigation into the production of sintered PFA aggregate', Building Research Establishment Publication. CP2/75, 1975.

[46] Floyd, S. B. and Engelleitner, W. H. 'The theory and practice of disc bailing', Institute for Briquetting and Agglomeration, Proceedings, Vol. 10, 1967, pp. 51-8.

[47] Sherrington, P. J. and Oliver, R. 'Granulation', Heyden, London, 1981.

[48] Messman, C. and Tibbetts, T. E. 'Elements of briquetting and agglomeration', Institute of Briquetting and Agglomeration, Las Graces N.M. USA.

[49] Lytag, 'The all-round lightweight aggregate', Lytag Limited, Hemel Hempstead, U.K.Aardelite ®, 'Een nieuw product, ennieuwe uitdaging', (Aardelite ®, 'A new product, a new challenge'). Aarding b.v., Nunspeet.

[50] Loggers, H. 'Hydrothermische verharde vormselgranulaten, bestaande uit chemische reactiecomponenten', (Hy-drothermal granulates, consisting of chemical compounds), NL, (C1. C04B35/14, C04B35/00), 28 November 1977, Appl. 7605527, 24 May 1976.

[51] Spanjer, J. J. 'The manufacturing of artificial gravel out of fly ash from powder coal-fired powerstations, an economical and environment friendly alternative for dumping', Coal Technology Europe 1983,Conference, Amsterdam, 1983.

[52] Donnely, I. R., Jons, E. and Webster, E. C. 'Synthetic gravel from dry flue gas desulphurisation end products', A/S Niro Atomizer Copenhagen, Denmark, Sixth International Ash Utilisation Symposium, Reno Nevada, March 1982, 23 pp.

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