UTILIZATION OF VARIOUS INDUSTRIAL WASTE MATERIALS AS FILLER IN AERATED CONCRETE: A REVIEW

Aboobackar Sidheeq M S[1], Indu Susan Raj[2], Dr. Elson John[3]

[1] PG Student, Department of Civil Engineering, Mar Athanasius College of Engineering, Kothamangalam
[2]Woman Scientist, Department of Civil Engineering, Mar Athanasius College of Engineering, Kothamangalam
[3]Professor, Department of Civil Engineering, Mar Athanasius College of Engineering, Kothamangalam

---***---

Abstract - *The construction Industry has reached boundless heights because of the development in cement and concrete research. But, along with the development in cement and construction, the cost of construction is also increasing. The cost of construction can be reduced by reducing the weight of the structural members. Aerated concrete is a better alternate to conventional concrete, which have low density, comparatively better strength, and simple composition improved durability etc. aerated concrete can be made by introducing voids by aeration process. Further the density of the concrete can be reduced by introducing industrials waste materials like quarry dust, rubber crumps and plastic granules which are non-recyclable in nature. These materials can be used as a partial replacement of fine aggregate, which reduces the non-recyclable products from the environment. This paper deals with the review of various literatures for utilizing the industrial waste as a filler material in aerated concrete. Utilization of the wastes comparatively gives strength along with reduction in densities. The possibilities of utilization of waste materials has been discussed.*

***Key Words*: Light Weight Concrete, Aerating Agent, Aluminium Powder, Rubber Powder, Plastic Granules, Quarry Dust.**

1. INTRODUCTION

Lightweight concrete (LWC) is a special type of concrete, which consists of lightweight coarse aggregate and a portion of fine aggregates or entire fine aggregates may be of lightweight. Density for Structural lightweight concrete varies in between 1440 to 1840 kg/m^3. Conventional concrete having a density varies in the range of 2240 to 2400 kg/m^3. For structural purpose the strength of concrete should be higher than 17.0 MPa.

Lightweight concrete can be classified into three based on various method of production:

First, using low specific gravity aggregates like porous lightweight aggregate, which have lower than 2.6. Such type of concrete production comes under lightweight aggregate concrete.

Second, introducing large air voids within mortar or concrete mass, and these voids and extremely fine voids made due to air entrainment must be clearly distinguished. Such type of concrete production comes under cellular, aerated, gas or foamed concrete.

Third, mix is made by omitting the entire fine aggregates resulting the presence of large number of interstitial voids. Generally normal weight coarse aggregates are used. . Such type of concrete production comes under no-fines concrete.

2. AERATED CONCRETE

The aerated concrete is one among types of lightweight concrete. It can be further subdivided into two types based on method of production. They are foamed concrete (Non-Autoclaved Aerated Concrete (NAAC)) and autoclaved aerated concrete (AAC). i) Foamed concrete is produced by injecting preformed stable foam or by adding a special air-entraining admixture known as a foaming agent into a mix of cement paste or cement mortar. ii) The AAC is produced by adding previously obtained amount of aluminum powder into the mortar mix.

In 1914, the Swedish architect Dr. Johan Axel Eriksson invented a mixture of cement, lime, water and sand that was expanded by the adding Al powder to generate H_2 gas in the mortar mix. Aerated concrete have low self-weight, lower consumption of aggregate, controlled low strength, and excellent thermal insulation properties. The density of aerated concrete lies within a range (800-140/m3), with appropriate control in the dosage of the Al powder, can be obtained for application to structural, partition, insulation, and filling grades.

3. PREPARATION OF AERATED CONCRETE

Unlike most other concrete applications, this concrete is produced using sand or aggregates having particle distribution size as of sand. Cement, Calcined gypsum, Quartz sand, and/or lime (mineral) and water are used as a binding agents. Aluminium powder is used at a rate of 0.05% – 2% by volume.

When aerated concrete is mixed and cast in forms, several chemical reactions take place which results up to 20% reduction of weight and thermal properties. Aluminium powder reacts with CaOH and water to form H_2 gas. The H_2 gas foams and bulks its volume by creating gas bubbles up to 3mm in diameter. Finally, these H_2 gas expels out and those voids are replaced by air. After 24 hour forms are removed and keeping it for curing for a period of 7 day and 28 days. Then compression test is done in order to find out the carry load of aerated concrete blocks.

4. MICRO STRUCTURE OF AERATED CONCRETE

The microstructure alters, either due to change in composition of filler materials or curing methods considerably affects the properties of aerated concrete. Presence of fly ash considerably change the micro structure due to the variations in hydration with time. Autoclaved products are basically stable. Similar to conventional concrete, there exists a transition zone at the void- paste interface but less porous, apparently voids acts as zero density aggregates [1]. Investigations based on microstructure shows that, when the microstructure changes both the compressive strength and drying shrinkage changes. When inclusion of industrials waste in the concrete mixes, it certainly changes the microstructure, but those changes shows enhanced properties up to a certain limit. XRD were conducted and results shows that, microstructure not only changes with the composition, it also changes with the curing methods that we adopt. AAC are stable with time, but non AAC changes its structure with time. Autoclaving gives the comparatively good strength with the better crystallinity [2]. In order to study the relations between structure and mechanical properties, test were conducted on aerated concrete at both fresh and hardened stage, it was observed that compressive strength decreases with increase in pore. Increase in pore is due to the presence of aerating agents like aluminium powder. Hence, increasing the dosage of Al powder badly affect the strength of concrete [3].

5. ADVANTAGES AND DISADVANTAGES OF AERATED CONCRETE

5.1 Advantages

i. ***Cost efficiency of construction-*** large dimension with low density blocks can be made which reduces the cost of construction.
ii. ***Low density and low thermal conductivity-*** Aerated concrete blocks have a density below 1800kg/m3 the thermal conductivity coefficient ranges in between 0.1-0.21, which makes the blocks light and warm.
iii. ***Good acoustic protection-*** when come in case of sound proofing, it ensures 10 times better than normal brick wall due to its porous structure.
iv. ***Fire safety-*** Aerated concrete is a non-combustible, fire-resistant material, has the first class of fire-resistance, far better than ordinary concrete.
v. ***Vapour permeability-*** aerated concrete have good vapour permeability, so that buildings made of aerated concrete can breathe and make the surrounding comfortable due to its same porous structure. Its vapour permeability coefficient ranges within 0.23 and 0.4.
vi. ***Environmental friendliness-*** aerated concrete doesn't contain any harmful ingredients, so it doesn't release any harmful substances. It's all made up of environmental friendly clean substances.

5.2 Disadvantages

i. For the manufacturing of aerated concrete blocks it requires a very expensive high power equipment and large production facilities are needed, but all this are one time investment only
ii. Low-volume production of blocks is not economical.
iii. Aerated concrete are porous in nature and have comparatively higher water absorption, so it should be plastered or decorative facades should be provided.

6. STRENGTH

Concrete has relatively higher compressive strength, but poor in tensile strength. Strength varies as the mix varies. As per IS 10262: 1982 gives the characteristic and design strength values for various grades of concrete. The standard mould of size 150x150x150mm and then the cubes should be kept for curing for 7, 14, 21 and 27days for ordinary mix and the compressive strength are tested as per IS 516: 1959. The compressive strength is depends on the quarry dust from where it was taken. The partial replacement by quarry dust showed an improved compressive strength [4]. The declination in compressive strength and the other mechanical properties due to the partial replacement of quarry dust can be compensated with the combined utilization of super-plasticizer and a mineral admixture such as RHA. Thus, it can be deduced that quarry dust can be a feasible partial substitute for fine aggregate to produce HSC with the combined utilization of super-plasticizer and RHA [5]. The 150 mm size concrete cubes, concrete cylinder of size 150 mm dia with 300 mm height were used in order to determine the compressive strength and split tensile strength respectively. The 7 and 28 days compressive strength and split tensile strength were higher than that of control mixes. But, when in case of the 3 days compressive and split tensile strengths was lower when compared with control mix. Further studies shows that a slightly less strength of concrete at early age, is beneficial to the durability of the concrete in some degree [6]. Fully replacement with quarry dust resulted low strength due to the presence of water, which exceeds the amount of water required for hydration process. Since, water absorption of quarry dust is low. The highest strength (28.0 N/mm2) given mix was the mix with 25% lateritic (Calabar lateritic soil) and 75% quarry dust at 0.54 w/c ratio [7].

Concrete mixes with tire chips and rubber crumb aggregates exhibited lower compressive and splitting tensile strengths than regular PCC, but had the ability to absorb a great amount of energy under compressive and tensile loads. When rubber crumps are used, up to 5% the compressive strength reduces by 5% only. But when increase to 7.5% and 10% o rubber, the compressive strength decreases by 10-23% [8]. Various studies shows that, if the rubber particles have rougher surface or if an additional pre-treatment is given, bonding with the surrounding matrix can be increased, thus the compressive strength increases. Pre-treatments like washing rubber particles with water to acid etching, plasma pre-treatment and various coupling agents. In acid pre-treatment, rubber particles are soaked in an alkaline solution (NaOH) for 5 min and then rinsed with water and showed an increase in the surface texture of the rubber particles. Results showed that water washed rubber particles achieved around 16% more compressive strength than untreated rubber particles, and further increment in strength was seen when treated with carbon tetrachloride [9].

The compressive strengths of the light weight aggregate concrete were reduced as the increase in percentage of PVC granules. This decrease in strength can be due to the weak bond between cement paste and PVC granules or lower elastic modulus than cement paste, or even the particle size distribution of plastic lead to lower level of packing [10].

There is a significant reduction in strength beyond a w/c ratio of 0.3. Addition of Al powder produces comparatively lower density. Up to 0.5 w/c ratio, as the dosage of Al powder increases the density is decreases proportionally. Beyond 0.5 w/c ratio, even though the density is decreasing, the strength obtained also too low. Suitable dosage and w/c ratio required has to be recognized based on the desired density and strength or strength to density ratio [11]. The IS method resulted in highly conservative results of compressive and flexural strengths primarily due to high cement content used in combination with low aggregate/cement and w/c ratio in comparison with other countries methods. When quarry dust partially replaced the natural sand, result 10-15% increase in the overall strength [12].

7. WORKABILITY

Workability is one among the physical parameters of concrete which affects the durability, strength and the appearance of the finished concrete surface. The workability of concrete depends on the w/c ratio and the water absorption capacity of the aggregates. If the w/c ratio is more which results to bleeding or segregation. W/c ratio varied from 0.5 and 0.8%, for 0.5% w/c cone height was 30cm, and for 0.8% w/c sample were totally collapsed [4]. Even though the partial replacement of quarry dust results in some minor negative impacts in workability, it can be solved by a good mix design and by the proper dosage of super-plasticizer [5]. Slump values of quarry dust with 0.55 w/c ratio are 37, 45, 50, 54, and 60mm for mixes of 0, 10, 20, 30, 40 and 50% of quarry sand respectively. It was observed that for same w/c ratio, slump value increases with increasing percentage of quarry dust. Workability was found lower for concrete mixes with increasing percentages of quarry dust, it might be due to the fineness of quarry dust, and obviously, finer particles require more amount of water in order to get closer packing [13]. The overall workability value of Quarry Rock Dust concrete is less compared to conventional concrete [12]. When combination quarry dust and lateritic soil are used, workability varies with in 0-150mm. i.e. true, shear and collapse slumps. Up to 50 percentage increase of lateritic soil resulted increase in workability at w/c ratio 0.5 and decreases with further increase in percentage of lateritic soil. [7].

The workability of lightweight aggregate concrete were reduced due the incorporation of plastic granules, and it can be improved by adjusting the dosage of super-plasticisers. [10].

8. DURABILITY

Durability of the concrete means that effect of concrete specimens when immersed in 5% solution of MgSO4, 5% solution of NaCl and 2N HCl acid solution, compressive strength and weight were observed at 28 days and 91 days. It was found that there is no loss of strength for immersion in MgSO4 and sodium chloride (NaCl) solution when comparing with the specimens which were immersed in normal water and the strength gain continue on almost all the specimens with no loss in weight. But, when in case of HCl, it was observed that there is a loss of strength and weight solution when comparing with the specimens which were immersed in normal water and the loss in strength was increasing as the no of days passes. Thus, MgSO4, NaCl has no adverse effect on the concrete specimens, but HCl highly deteriorate the strength of concrete [14].

The durability of concrete under sulphate was higher than conventional concrete when partial replacement of fine aggregate with quarry dust. When the specimen immersed in 7.5% sulphate solution, both 28 days and 90 days shows similar effect. But, when immersed in MgSO4 solution, influence of anti-corrosion factor was not obvious [8]. The Durability of Quarry Dust concrete under sulphate and acid action is greater than the Conventional Concrete [6].

Concrete made with 35-40% GGBFS along with cement have increased durability properties such as increased resistance against Cl penetration also increases the resistance against sulphate attack and alkali silica reaction. Further finer GGBS have improved strength and durability properties, because CaO formed during the hydration process can activate the GGBFS reaction with cement. Applications of optimal percentage of cement replacement by GGBFS can be spread out to all structural elements, bridges etc. [15].

9. CONCLUSIONS

i. Usage of granite in the conventional concrete as Fine aggregate was positively affected on properties of fresh and hardened concrete.
ii. The reaction of Al powder with that of lime will reduces density, which affects the strength also. For regulating reduction in strength, utilization of marble powder in replacement of cement which will fill the micro pores and increase the strength.
iii. Utilization of industrial wastes like rubber, quarry dust and plastic wastes leads to energy efficient concrete.
iv. Utilization of industrial wastes play a vital role in reducing the non-recyclable waste particles.
v. Improved properties like sulphur attack resistance, high thermal insulation, abrasion resistance etc.
vi. Utilization of GGBFS and industrial wastes in concrete production can reduce energy costs in manufacturing of natural materials, reduced land disposal and reduced greenhouse gases.
vii. This study would form a part of useful information for recycling scrapped PVC plastic pipes, rubber crumps and quarry dust in lightweight concrete mixes.
viii. Test results show that these industrial wastes are capable of improving hardened concrete performance.
ix. Fully replacement of fine aggregate with quarry dust, plastic granules and rubber crumbs are possible. It is advisable to carry out trail mixes in order arrive a proper dosage of super-plasticizers, w/c ratio, aluminium powder dosage etc.

REFERENCES

[1]. Narayanan, N., & Ramamurthy, K. (2000). Microstructural investigations on aerated concrete, 30, 457–464.

[2]. S. N. Raman, T. Ngo, P. Mendis, and H. B. Mahmud, "High-strength rice husk ash concrete incorporating quarry dust as a partial substitute for sand," Constr. Build. Mater., vol. 25, no. 7, pp. 3123–3130, 2011.
[3]. J Alexanderson. Cem Concr Res. 1979, 9(4), 507-514.
[4]. S. L. Chauhan and R. A. Bondre, "Partial Replacement of Sand by Quarry Dust in Concrete," Int. J. Sci. Res. Publ., vol. 5, no. 7, pp. 2250–3153, 2014.
[5]. N Narayanan; K Ramamurthy. Cem Concr Res. 2000, 30(3), 457-464R. Siddique and T. R. Naik, "Properties of concrete containing scrap-tire rubber - An overview," Waste Manag., vol. 24, no. 6, pp. 563–569, 2004.
[6]. M. S. Hameed and A. S. S. Sekar, "Properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregate," J. Eng. Appl. Sci., vol. 4, no. 4, pp. 83–89, 2009.
[7]. Ukpata, J. O., Ephraim, M. E., & Akeke, G. A. (2012). Compressive strength of concrete using lateritic sand and quarry dust as fine aggregate, 7(1), 81–92.
[8]. Materials, B. (2012). Scrap-tyre-rubber replacement for aggregate and filler in concrete, (November).
[9]. R. Siddique and T. R. Naik, "Properties of concrete containing scrap-tire rubber - An overview," Waste Manag., vol. 24, no. 6, pp. 563–569, 2004.
[10]. S. C. Kou, G. Lee, C. S. Poon, and W. L. Lai, "Properties of lightweight aggregate concrete prepared with PVC granules derived from scraped PVC pipes," Waste Manag., vol. 29, no. 2, pp. 621–628, 2009.
[11]. Kumar, E. M., & Ramamurthy, K. (2015). Effect of fineness and dosage of aluminium powder on the properties of moist-cured aerated concrete. CONSTRUCTION & BUILDING MATERIALS, 95, 486–496.
[12]. Ilangovana, R., Mahendrana, N., & Nagamanib, K. (2008). Strength and durability properties of concrete containing quarry rock dust as fine aggregate, 3(5), 20–26.
[13]. T. K. Lohani, M. Padhi, K. P. Dash, and S. Jena, "Optimum utilization of quarry dust as partial replacement of sand in concrete," Int. J. Appl. Sci. Eng. Res., vol. 1, no. 2, pp. 391–404, 2012.
[14]. Nguyen, L., Asamoto, S., & Matsui, K. (2018). Sorption isotherm and length change behavior of autoclaved aerated concrete. Cement and Concrete Composites, 94(December 2017), 136–144. https://doi.org/10.1016/j.cemconcomp.2018.09.003.
[15]. Mccarter, W. J., & Taha, H. M. (2018). Eco-friendly GGBS Concrete : A State-of-The-Art Review Eco-friendly GGBS Concrete : A State-of-The-Art Review. Eco-Friendly GGBS Concrete : A State-of-The-Art Review Eco-Friendly GGBS Concrete : A State-of-The-Art Review, IOP Conf. https://doi.org/10.1088/1757-899X/330/1/012057.