Utilization of Waste Autoclaved Aerated Concrete

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***Abstract*—The rapid progress in construction industry is also influencing to the equivalent construction materials. Autoclaved aerated concrete (AAC) is one of the construction waste materials. Thus to elucidate the dumping problem of AAC the waste AAC can be reused in an effective way to achieve sustainability. The Autoclaved aerated concrete particles (AACP) are used as bio filter carriers in biological aerated filters for waste water treatment. The natural materials used in green roofs are substituted by granular AAC. This review targets at studying the features of AAC and its reuse in advance waste water treatment and in green roofs.**

***Keywords*— AACP,CAC, BAF, HRT, $NH_3 - N, TOC, TN, PO_4{}^{3-}$**

I. INTRODUCTION

Concrete is greatly used as construction material in modern days. Autoclaved aerated concrete (AAC) also recognized as autoclaved cellular concrete (ACC), autoclaved lightweight concrete (ALC) is a special kind of concrete where cement, lime, water, sand and a blowing agent are mixed. AAC went into manufacture in Sweden in 20's and became very common. AAC products include blocks, wall panels, floor and roof panels, cladding panels and lintels

No aggregates larger than sand are used in AAC. Quartz sand, calcined gypsum, lime (mineral), cement and water are used as a binding agent. Aluminum powder is used at a rate of 0.05%–0.08% by volume (depending on the pre-specified density). In the AAC manufacture process, during the hardening period, aluminum is added and a gas advances within the structure of the concrete. The pH reaction environment is basic and aluminum, due its amphoteric behavior, melts and oxidizes, allowing gaseous hydrogen growth. The hydrogen gas foams and doubles the volume of the raw mix creating gas bubbles. At the end of the foaming process, the hydrogen escapes into the atmosphere and is replaced by air.

$$2Al\ (s) + 3Ca(OH)_2 + 6H2O \rightarrow 3CaO \ .\ Al2O_3 \ .\ 6H_2O + H_2(g)$$

Later, porous blocks, still moist, are heated within autoclaves with quite low temperature, 190°C, and high-pressure, 12 bar, for about 14 hours. In this time, there is a hydrothermal treatment and the formation of tobermorite, whose chemical formula is

$$5CaO \ .\ 6SiO_2 \ .\ 5H_2O$$

Thus the crystals of calcium silicates which strongly influence the mechanical properties of AAC are formed.

The important features of the AAC are:

- Porosity
- Light weight and density
- Thermal insulation
- Acoustic insulation
- Transpiring
- Low environmental impact

AAC has been produced for more than 70 years, and it offers several substantial advantages over other cement construction materials, one of the most important being its lower environmental impact.

II. INNOVATIVE WASTE WATER TREATMENT WITH WASTE AUTOCLAVED AERATED CONCRETE

Autoclaved aerated concrete particles (AACP) were verified in biological aerated filters (BAF) as biofilter carriers to resolve the disposal problems of construction wastes. Biological aerated filters (BAFs) are an evolving wastewater treatment technology designed for a wide range of municipal and industrial applications. The term BAF came from the mixture of air and the filtering action of the bacteria. A BAF normally consists of medium that treats carbonaceous and nitrogenous matter using biomass fixed to the media and arresting the suspended solids in the media. BAF is a flexible reactor, which offers a small footprint process option at various stages of wastewater treatment. BAFs usually treat settled sewages by eliminating chemical oxygen demand (COD) and ammonia (NH3-N). BAFs are fixed-film reactors that use biofilter carriers with a high specific surface area and high total porosity for waste water treatment. The medium allows the reactor to act as a deep submerged biofilter and integrates suspended solids ejection.

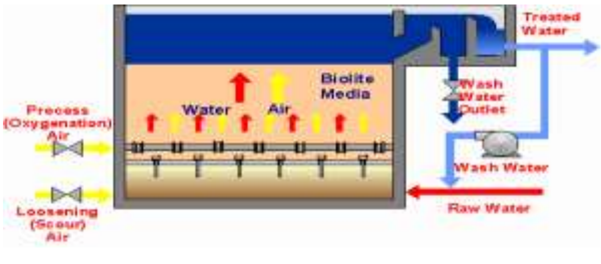

FIG. 1 BIOLOGICAL AERATED FILTERS

2.1.BAF setup and waste water quality assessment

Two lab-scale biofilter columns were made from polyvinylchloride pipes 6 cm in diameter with a depth capable of holding 150 cm of biofilter carrier. One of the two BAFs was packed with AACP and the other with CAC. The test was divided into four phases. During each test phase, the operating conditions of the two BAFs were alike (Table 1). The hydraulic retention time(HRT) ranged from 0.5 h to 7 h. City wastewater samples were collected from the inlet and outlet pipes of the two BAFs. The physical characterization of AACP and CAC and the effect of HRT on TOC,TN etc was done.

Table 1.

Sample	Operating conditions		
	PH	T (◦C)	HRT(h)
Stage1	6.3(±0.5)	25-30	7(±0.5)
Stage2	6.2(±0.5)	25-30	3.25(±0.8)
Stage3	6.6(±0.5)	20-25	1.75(±0.5)
Stage4	6.9(±0.5)	18-23	0.5(±0.1)

2.2.Results and discussion points

2.2.1.Physical characterization of AACP and CAC

In waste water treatment filter media are essential to have high surface area and high porosity and the selection of the filter media plays an important role in maintaining a high amount of biomass. By the physical characterization of AACP and CAC, AACP shows higher porosity, larger surface area, lower bulk, and apparent density than CAC though both the filter media had a mean diameter of 4-9mm. The main minerals in CAC are heamatite and quartz while in AACP is silica, calcium oxide, aluminium oxide. In addition to transition metals it consist of small amounts of alkali and alkaline earth metals which makes the microorganisms to consume the biolfilter media. The lack of the heavy metals also specifies that the biofilter media are suitable for microbial growth.

2.1.2.Cast thin section of AACP

The unevenness and porosity of open AACP surface advantage the environmental microorganisms fixed on the surface. The environmental microbial biofilm attached to the AACP surface is a highly hydrophilic substance under constant wastewater flow. Environmental microorganisms can be transmitted through AACP into the internal pores and the biofilm can attach to the AACP surface. The waste water flow can be separated into three layers: anoxic, aerobic and aqueous adhesion. The microorganisms in the biofilm generate zonation and conditions for instantaneous nitrification and denitrification. The intergranular pore textures are noticed in the thin section. Thus, AACP have a large volume of internal pores that can adapt guest microbes. These inter connected pores are approximately 100–250 μm in size and most bacteria are 0.5μm or less in diameter. Thus, the environmental microorganisms can attain a sustained growth of population in the open pores.

The rough surface of AACP is described by a netted texture and a porous structure that offer shelter from the wastewater shear forces. The microstructure of the internal cross-section shows that the prepared AACP are highly porous with elliptic opening pores. Macropores form inside the AACP when aluminum powder set off a chemical reaction under alkaline conditions to release hydrogen during autoclaving test. The equations can be expressed as follows:

$$AL_2O_3 + 2NaOH = 2NaAlO_2 + H_2O$$

$$2Al + 6H_2O = 2Al(OH)_3 + 3H_2 \uparrow$$

$$Al(OH)_3 + NaOH = 2NaAlO_2 + H_2O$$

The Biofilm overlaps were located on the surface of the AACP. Filamentous-shaped and chain shaped biological bacteria were spotted. The biofilm overlaps exhibited extreme growth on the AACP because of the rough surface. This result induced the biofilm thickness at the steady state. Thus, the optimum thickness of the biofilm and superior performance of the BAF can be reached. The AACP BAF had favorable $NH_3-N, TOC, TN, PO_4{}^{3-}$ removal efficiencies because of the ample microorganisms and thick biofilm of AACP.

2.1.3. Impact of HRT on $NH_3-N, TOC, TN, PO_4{}^{3-}$ eliminations

HRT (hydraulic retention time) is a critical parameter in the biological waste water treatment. At different HRT's the normal removal rates for NH3-N, TN, TOC, and PO43− were observed. It was observed the efficiency of the removal of NH3-N, TN, TOC, and PO43− decreased with the decrease in HRT.

III.GREEN ROOFS

The substitution of the natural lightening material (lapillus and pumice stone) in green roofs is done by the granular waste AAC and thus it is proven that the soil-concrete mixture has characteristics (chemical and physical) similar to the soil-natural material mixture.

3.1. Chemical analysis methods

The sample soil-concrete mixture is taken. The first step is the determination of PH so as to acquire a neutral soil-waste AACP to create a neutral environment for plants. The second step is the determination of organic matter and ashes.

3.1.1 .PH determination

As per the standards the sample having a mass of 25g must be added to 300ml of distilled water. Five different samples were taken. Each sample was added to 300ml of distilled water in a plastic container closed compactly with a stopper and the put into a shaker for one hour keeping a constant temperature around (23±2)°C. The PH of the sample is taken by the PH meter. The water soak up the solid sample characteristics dispersed in it and the suspension inside the container gives the PH values.

Sample	Peat weight (g)	AAC weight (g)	Total weight (g)	PH
AAC	0	24.42	24.42	10.05
Peat	25.59	0	25.59	6.6
20%AAC 80%peat	20.23	4.98	25.21	6.98
30%AAC 70% peat	17.23	8.12	25.35	7.33
40%AAC 60% peat	14.89	10.16	25.05	7.78

Table 2

Results of pH analysis made on five different samples

All the results display alkaline PH of the concrete. The mixture of 30% AAC and 70% peat is used for the other tests as it gives a neutral PH of 7.33.

3.1.2. Organic matter determination

The organic matter has a vital role in the soil structure, because organic compounds ultimately act on the elements accessibility. They create an obstruction to the water permeability in the direction of the deep layers, holding it in a reversible way and adding to the aggregation of mineral particles. Organic compounds intrude on ion exchange, making a more difficult solubilization and elements leaching.

In this experiment the sample is placed in an oven at a temperature progressively increasing and weighing its specimen; a weight loss should be noted due to the organic part that degrades before all other substances of which the sample is made. The samples are measured in an open environment and in a glove box to evade the absorption of moisture.

Table 3

The table is the summary of the test of evaluation of the organic substance within a AAC sample, performing the weighing step in an external environment and in a sealed environment.

Measurements	Weight(g) Sample1 External environment	Weight Sample2 Glove box
M0	55.890	56.032
M1	61.23	61.44
M2	60.905	60.98
Worg	4.073%	5.9%

The results show that the value of lost mass in an open environment is less because AAC has a high hygroscopic degree. The standards designate that this percentage is entirely made up of organic components of the sample. In this case, it is possible that part of this percentage relates to a weight loss corresponding to the evaporation of hydration water.

3.2. Physical analysis methods

The physical characteristics of the sample composed of 70%peat and 30%AAC is done by the laboratory tests.

3.2.1. Measurement of the water content

The sample is placed in a container with known mass (mc) and the total mass is remarked as m1. The container is placed in oven at about 100 to 105℃ for a minimum of 17h. The sample is then taken out from the oven and kept in dryer to cool down to environment temperature. The dry specimen and the container are weighted as m2.

Table 4

Results of water content determination

Container mass(mc)	Container +wet soil(m1)	Container+dry soil(m2)	Moisture content
18.73 g	35.98	25.23	165.38%

The moisture content is calculated as W=(m1-m2)/(m2-mc)*100

3.2.2. Determination of particle density and water absorption

The material is sieved to obtain the grain size between 4.25 and 11. As per the standards the sample must have particle between 4mm and 31.5mm. The pycnometer capacity is 500ml and the sample seizes a volume between 250 and 300ml.

Two experiments are carried out with two different samples:-

-two samples of AAC with a volume of 275 ml;

- two samples of the mixture 30%AAC and 70%peat: 250 ml of the mixture, about 27.85 g of dry soil and 43.62 g of AAC, for a total of 71.47 g.

First the dry sample is placed inside the pycnometer (tare noted as m1). Then the value m2 is noted by weighing the pycnometer with the sampe. The pycnometer is filled with water, up to the reference mark, and the counting time is started. The pycnometer is shaked after 5 min to remove the air bubbles formed due to grains. The container is filled again, up to the reference mark, and the outer surface is dried carefully. The specimen is weighted as M5. All the operations described above are repeated after 24 h and it is assigned to the last value of the mass the symbol M24. After this measurement, only water is removed from the pycnometer and the aggregate is shifted on a dry tissue to remove surface water, rolling it gently. Wet aggregate mass is noted as Mw.

The results of this test are shown in the table 5 with all the recorded mass values during the test.

The particle density of the light weight concrete is calculated for each sample according to the equation-

Particle density= $\frac{(m2-m1).\rho w}{m1+(Vp.\rho w)+m-M}$

The denominator $m1+(Vp.\rho w)+m-M/\rho w$ resembles to the volume occupied by the sample, corresponding to a lost volume of water to reach 250 ml of the pycnometer. The equation arises from a ratio of the mass of the sample and its density. Table 6 shows the results of the bulk density of the samples. Density values are somewhat larger than that of water (0.9973 Mg/m^3), according to the fact that part of the material floats inside the pycnometer.

Water absorption is analyzed with the following equation:

Wf = $\frac{Mw-(m2-m1)}{(m2-m1)}$ .100

Table 7 displays the results of the percentage of the mass of water absorbed respect to the dry mass. Apparently, the result of water absorption by the mixture is very high, but it is justified by the result of the test carried out for the water content just for the specimen containing peat. In fact, the soil has an absorption capacity of about 163.52% of its dry weight in normal conditions; therefore, the value of 218.574% relative to the absorption of water by the mixture is an acceptable value.

Table 5
Samples 1 and 2 are just of granular AAC, while samples number 3 and 4 are made with 30% of AAC and 70% of peat.

Measurements	**Symbol**	**Weight (g) Sample1(AAC)**	**Weight (g) Sample2(AAC)**	**Weight (g) Sample3(Mix)**	**Weight (g) Sample4(mix)**
Tare pycnometer	m1	202.4	207.23	202.34	207.2
Dry gross weight (pycnometer+sample)	m2	295.6	299.98	274.83	270.7
Dry net weight	M	92.5	92.67	71.5	71.4
Wet gross weight	M	767.7	774.58	700	728.1
Wet gross weight after 5 min	M5	771.2	780.3	756.89	764.8
Wet gross weight after 24h	M24	773	781.9	791.89	797.67
Wet net weight	Mw	147.23	148	238.9	221.5

Table 6
Values of particle density of AAC and the mixture.

	Sample 1(AAC)	**Sample 2(AAC)**	**Sample 3(mix)**	**Sample 4(mix)**
γ_a	4.023Mg/m^3	5.97Mg/m^3	1.46Mg/m^3	0.985Mg/m^3
$\gamma_{a(average)}$	4.99Mg/m^3		1.2225Mg/m^3	

Table 7
Percentage of mass of absorbed water respect to dry mass. Samples 1 and 2 are made of AAC; samples 3 and 4 are made of mixture (30% of AAC and 70% of peat).

	Sample 1(AAC)	**Sample 2(AAC)**	**Sample 3(mix)**	**Sample 4(mix)**
Wf	57.67%	59.98%	223.457%	213.691%
Wf(average)	58.825%		218.574%	

IV. CONCLUSIONS

Based on above study following conclusions are drawn:

(1) AAC is a lightweight concrete which contains fly ash, lime , cement, gypsum, water and pore generating aluminium powder. It has well established porous structure, larger surface area than the CAC which helps to advance the microbial communities and increases the pollutants removal efficiencies. The BAF test showed that the AACP was superior over the CAC and can be effectively used to for the *on* $NH_3 - N, TOC, TN, PO_4{}^{3-}$ removal at suitable HRT.

(2) All the analyzed physical and chemical characteristics of the AAC waste are comparable to those reported in literature for a natural lightening material such as lapillus or pumice rock. The found results permit us to state that granulated AAC waste can be used as lightning material within a structure for a green roof.

V. ACKNOWLEDGMENT

The authors acknowledge the support by Sinhgad college of engineering, Savitribai Phule University Pune.

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