

# **PROSPECTIVE BENEFITS OF USING ACTIVATED CARBON IN CEMENT COMPOSITES- AN OVERVIEW**

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## **ABSTRACT**

*An exhaustive study of available literature on use of activated carbon in cement composites was done. Adsorptive nature of activated carbon can be effectively used to remove toxic air pollutants such as nitrogen oxide, volatile organic compounds by adsorbing to concrete elements (chimneys, tunnels etc.). Experimental research work carried out on cement composites containing activated carbon revealed its potential ability to improve physical, mechanical and durability properties of cement composites. A comprehensive review of selected literature was carried out and the significant findings are presented in this paper. Researchers across the globe had experimentally showed that presence of activated carbon at 1 to 4% in cement composites positively influence various properties of cement composites.*

**Keywords:** Activated Carbon, Adsorption, Cement, Concrete, Compressive strength, Durability

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## **1. INTRODUCTION**

One of the widely and popularly used construction materials is concrete. Quality of human civilisation in terms of infrastructure, habitation and transportation had greatly been affected by this construction material. Cement concrete is commonly used in buildings and other important engineering works where strength and durability is of prime importance. Concrete is made from a properly proportioned mixture of hydraulic cement, water, fine and coarse

aggregates and, often, chemical admixtures and supplementary Cementitious materials (SCMS) [1]. The chemical reaction called hydration in concrete results in gain of strength. Portland cement concrete is a composite material made up of both fine and coarse aggregate materials combined together with fluid cement (cement paste) which hardens over time. Most frequently a lime-based cement binder such as Portland cement but sometimes with other hydraulic cements such as calcium aluminate cement. The cement concrete in which no reinforcement is provided is called plain cement concrete or mass cement concrete. This type of concrete is strong in taking compressive stresses but weak in taking tensile stresses. Physical and mechanical properties of Ordinary Portland cement is shown in Table 1 and 2 respectively.

**Table 1:** Physical tests of ordinary Portland cement

<b>Blaine</b>	<b>3.250 cm<sup>2</sup>/gm</b>
<b>Autoclave Expansion</b>	0.02 mm
<b>Fineness</b>	400 MAX

**Table 2:** Compressive strength of ordinary Portland cement

<b>03 Days</b>	<b>230 kg/cm<sup>2</sup></b>
<b>07 Days</b>	305 kg/cm <sup>2</sup>
<b>28 Days</b>	420 kg/cm <sup>2</sup>

## 2.1. ACTIVATED CARBON

Activated carbon is carbon created from carbonaceous source materials such as bamboo, coconut husk, willow peat, wood, coir, lignite, coal, and petroleum pitch. Activated carbon can be produced by physical activation or chemical activation. A form of activated carbon known as activated charcoal is processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reactions. Activated is sometimes substituted with active. Different classifications of activated carbon include: powdered activated carbon, granular activated carbon, Extruded activated carbon, Bead activated carbon, Impregnated carbon and Polymer coated carbon.

### 2.1.1. Process of preparing activated carbon

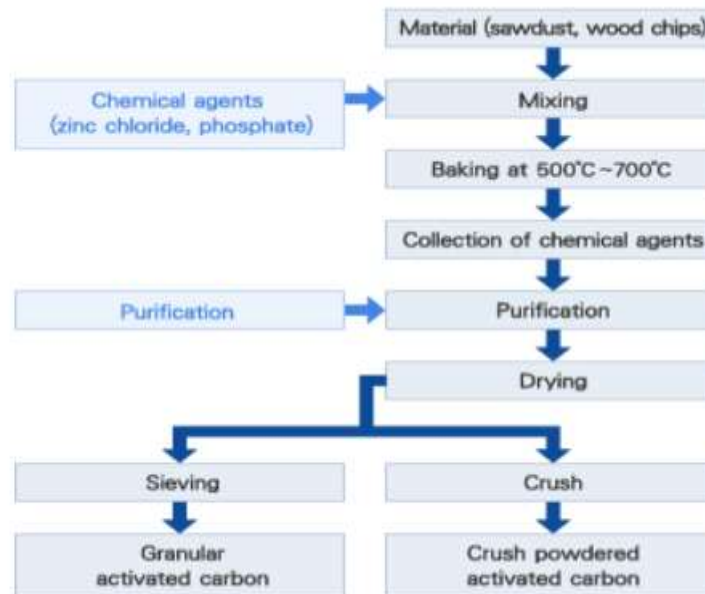
a) Physical activation: Hot gases are used to transform source material into activated carbons. Air is introduced to burn out the gasses, creating a graded, screened and de-dusted form of activated carbon. This is generally acquired by one or a combination of the following processes:

- Carbonization: Material with carbon content is pyrolyzed (thermal decomposition of material at elevated temperature in an inert atmosphere)[2] temperatures in the range 600–900 °C, usually in inert atmosphere with gases like argon or nitrogen
- Activation/Oxidation: Raw material or carbonized material is exposed to oxidizing atmospheres (oxygen or steam) at temperatures above 250 °C, usually in the temperature range of 600–1200 °C.

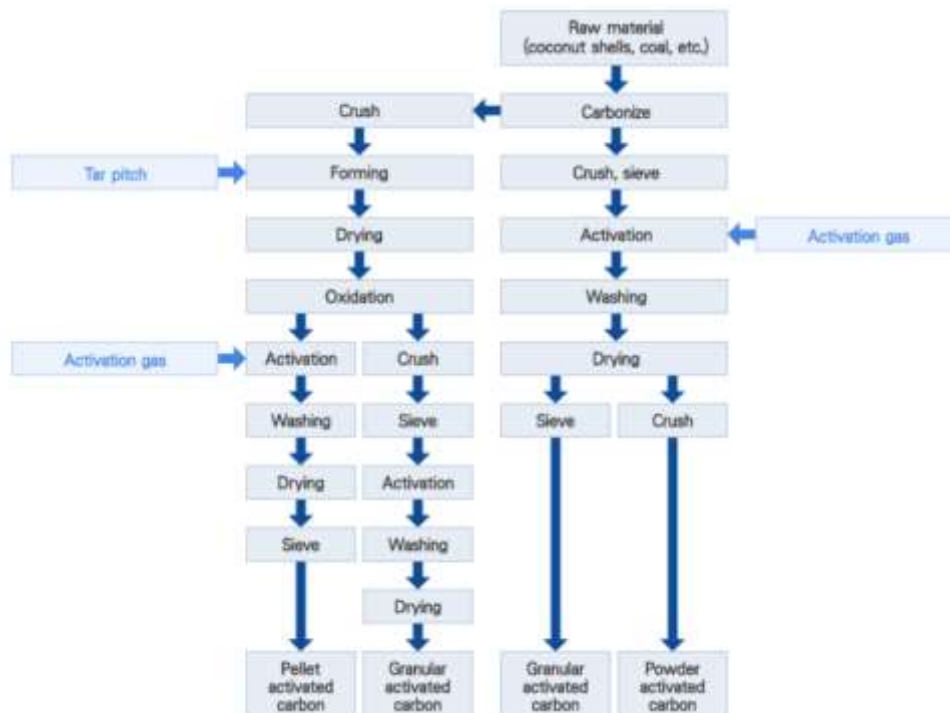
b) Chemical activation: Before carbonization, the raw material is impregnated with certain chemicals. The chemical is usually an acid, strong base, or a salt (phosphoric acid,

potassium hydroxide, sodium hydroxide, calcium chloride, and zinc chloride 25%). Then, the raw material is carbonized at lower temperatures (450–900 °C). It is believed that the carbonization or activation step proceeds concurrently with the chemical activation.

Chemical activation is favoured over physical activation owing to the lower temperatures and shorter time needed for activating material. [3]. Various steps in preparing activated carbon are given in figures 1 and 2.



**Figure 1:** Chemical Process for the preparation of activated carbon [4]



**Figure 2** Physical process for the preparation of activated carbon[5]

### 2.1.2. Physical properties of activated carbon

Various physical properties of activated carbon is shown in Table 3.

**Table 3:** Technical specification of granular activated carbon

Properties	Grade available in market carbon		
	GL-50	GL-70	GL-100
<b>Raw Material</b>	Coconut Shell Charcoal		
<b>Appearance</b>	Black granules	Black granules	Black granules
<b>Particle Size</b>	Any sieve size	Any sieve size	Any sieve size
	4/8, 8/16, 8/30	4/8, 8/16, 8/30	4/8, 8/16, 8/30
	8/50, etc	8/50, etc	8/50, etc
<b>Bulk Density</b>	0.55+0.05 gm/cc		
<b>Carbon Tetra Chloride Adsorption</b>	30%	45%	60%
<b>Iodine Adsorption mg/gm</b>	500mg/gm+25	750mg/ gm+25	1000mg/ gm+25
<b>Total Surface Area (min)</b>	500 m <sup>2</sup> /gm	750 m <sup>2</sup> /gm	1000 m <sup>2</sup> /gm
<b>Ball Pan Hardness No.</b>	95	90	90
<b>pH</b>	9 to 10	9 to 10	9 to 10
<b>Ash Content</b>	5% Max	5% Max	5% Max
<b>Moisture</b>	5% Max	5% Max	5% Max

### 3.1. Potential benefits of using activated carbon in cement based compounds.

Presence of activated carbon made from coconut shell in concrete had found to reduce the amount of radon. It is observed that the adsorption mechanisms of activated carbon towards the radon gas in the solid and in the air were alike.

Reported research works shows that activated carbon had less effect on the strength of concrete, however, they have greater influence on the constructability and durability of concrete.[2] Powdered activated carbon decreased the air void content and affected the specific surface area and the spacing factor . The addition of a small amount of activated

carbon considerably increased the adsorption of harmful gases; which limited environmental pollution. Activated carbon could provide pollutants showed adsorbing properties and improved fire resistance of concrete. The addition of activated carbon in the fly ash cement mortar improved compressive strength[9].

### **3.1.1. Advantages of activated carbon concrete:**

1. Activated Carbon can be used in light weight concrete and it act as a binder in lightweight concrete.
2. Increases in percentage of activated carbon would reduce the thermal co
3. Activated carbon reduced the content of NO<sub>x</sub>(nitrogen dioxide, nitrogen oxides) from pollution in tunnels and parking garages.
4. The percentage of activated carbon is more can increase the compressive strength.
5. The use of Activated carbon results higher strength in fly ash mortars.
6. Activated carbon due to its structure developed, large surface area, strong adsorption capacity, high mechanical strength, low bed resistance, good chemical stability, easy regeneration, durability and other advantages, received great attention and extensive research, known as 21 centuries one of the most advanced materials.
7. Activated carbon reduces the presence of pores in conventional concrete, which enhances the performance of concrete.
8. Activated carbon has benefits in concrete it is better workability and ultimate strength.

## **4. REVIEW OF LITERATURE**

**B.Chowdhury [2004]** has done experimental investigation for blocking the moisture in cement by the use of activated carbon. Most of the problems faced in concrete structures is due to moisture attack. Open voids in concrete contains moisture due to its porosity. It occurs on prepared cement during the stages of mixing and hydration. This issue can be resolved by adding vinyl polymer and activated carbon which would block moisture ingress. This method is called Macro Defect Free (MDF) formulations. Comparison of results of non activated carbon specimen and activated carbon containing specimens showed the potential ability of activated carbon in moisture resistance [10].

**Mehrdad Mahoutian et al [2015]** studied the air void characteristics of concrete containing class F fly ash and activated carbon. Five mixes containing various percentages of activated carbon and fly ash were studied. The dosage of activated carbon was 0%, 2%, 5% and 10% by mass of fly ash. The authors reported that powdered activated carbon reduced the air void content in concrete which in turn led to higher compressive strength. Type of fly ash, water to binder ratio air entraining admixtures and percentage of powdered activated carbon used potentially affect strength and air void characteristics of concrete mixes [8].

**N.J. Krou et al [2015]** reported that presence of activated carbon in hydrated cement paste reduces the reactivity of volatile organic compounds in cement mortar. Volatile organic compounds (VOCs) increases pulmonary diseases for various people to the release of indoor air from confined spaces such as residential buildings, office buildings, underground garages, industrial plants and ware house. VOCs such as formaldehyde (paint, wood materials, ceiling tiles), acetaldehyde(coffee, bread, ripe fruits), benzene(tobacco smoke, stored fuels, exhaust from cars) or toluene(paint thinners,). Activated carbons are good adsorbents of VOCs. Activated carbons can be used as an additive material in cement concrete to improve the

quality of air. Up to 50°C high amount of toluene has been adsorbed by powdered activated carbon [11].

**M.Di Tommaso and I.Bordonzotti [2016]** had conduct experiment on concrete containing activated carbon. Result of the study showed that improving performance and durability of concrete were resulted by presence of activated carbon in concrete. Various percentages of activated carbon used were 0.48%, 1.06% and 1.43%. Results of the test such as compressive strength, flexural strength and resistance to sulphate attack showed that the results were maximum at 0.48%, 1.06% and 1.43% respectively [9].

**Venkata Krishna Chaithaniya .C and Dr. Neeraja D[2016]** experimentally studied the effects of partial replacement of cement and fine aggregates with activated carbon in concrete. Activated carbon when used as binder in concrete will reduce the pores in concrete thus improve the performance of concrete. In this study cement was partially replaced by activated carbon at various percentages such as 15%, 30% and 45% by mass .Fine aggregates was partially replaced by activated carbon by mass 15%, 30% and 45%. The compressive strength and tensile strength were maximum for concrete with 30% partial replacement, while flexural strength gain maximum strength at 15% partial replacement. Specimen prepared with mixes which has cement replaced with activated carbon showed more strength than specimen partially made with concrete containing activated carbon as partial replacement for fine aggregate [12].

**Nuria Husillos Rodriguez et al[2016]** experimentally showed that the activated carbon can be used as an alternative fuel. The feasibility of valorising waste material as an alternative fuel to replace oil coke in Portland clinker furnaces was experimentally studied. Activated carbon has 18% lower calorific value than oil coke. Activated carbon combustion yields ten times more ash than oil coke combustion. The presences of carbon ash has no impact on hydration of cement which is prepared in the ash clinker [13].

**Yonggui Zhang et al[2016]** experimentally showed that activated carbon can reduce the effect of radioactive elements and radon exhalation rate in concrete. Four different types of activated carbons were used for the study. Activated carbons derived from coconut shell, fruit shell, wood and coal were used. Activated carbon was used at 1%, 3%, 5%, 10% and 15%. The mixes containing activated carbon at 1 % to 5% showed bleeding. Addition of activated carbon at 10 and 15% showed zero bleeding. The results of Radon exhalation rate experiments on concrete revealed that the reduction in exhalation rate was 44.3%, 47.1%, 29% and 19.2% respectively for mixes containing activated carbon derived from nutshell, coconut shell, coal and wood. The author concluded that the carbon content from coconut shell highly reduced radon exhalation rate of concrete [14].

**Chaocan Zheng et al [2017]** studied the effect of activated carbon containing fly ash in cement composites. Results of the study showed increased compressive strength and enhanced microstructure it was found that by adding activated carbon at 4% by mass in cement mortar containing 20% fly ash considerably increase the compressive strength. Scanning electron microscope images of selected hydrated pastes showed that activated carbon in fly ash cement system could fill the gap of hydration products such as, calcium silicate hydrate and ettringite [15].

**Ismael Justo-Reinoso et al [2018]** experimentally studied influence of activated carbon on various properties of cement mortar. Granular activated carbon was used to partially replace of fine aggregate. Addition of activated carbon increased the compressive and tensile strength of mortar. Specimen tested porosity and critical pore diameter values were observed to reduced by the addition of granular activated carbon at  $\leq 1\%$  by mass [16].

**MassinissaLekkam et al [2019]** investigated the potentiality of the reuse of saturated activated carbon in Cementitious materials. Experiments were conducted on cement composites such as cement pastes and mortars. Activated carbon was used at different percentages (0.5, 1, 2, and 4%). The authors reported that the use of saturated activated carbon powder results in denser micro structure by filling the pores and improve the quality of products of hydration reaction. Workability time of concrete was affected by presence of saturated activated carbon. The authors also reported about the environmental benefits of using saturated activated carbon in Cementitious composites, 4% saturated activated carbon as cement substitution results in 4% reduction of carbon dioxide emission to the atmosphere [17].

## 5. CONCLUSION

- ❖ Carbon black or activated carbon is a black coloured finely separated petals or powder.
- ❖ Activated carbon is one of the most promising materials of 21<sup>st</sup> century due to its structure, adsorption capacity high mechanical strength good chemical stability and durability.
- ❖ Potential benefits of using activated carbon in concrete is not explored completely.
- ❖ Researchers had reported that 1 to 4 % percentage of activated carbon in cement concrete / cement composite significantly improve its properties.
- ❖ Further extensive studies are needed to explore the prospective benefits of using activated carbon in concrete.

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