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Addressing the Issue of Microparticle Size Pyrolysis Carbon Black (PCB) by Adding to the Concrete Mixture

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Abstract: **MAX 250 words** Tire waste is one of the world's major environmental solid waste problems. Used tires cannot be handled in landfills or burned because they create noxious vapors that are harmful. Therefore, a variety of methods for the treatment of used tires have been proposed. The most advantageous method for disposing of garbage is thought to be tire pyrolysis. By pyrolyzing waste tires, carbon black (PCB) is produced as a byproduct as well as gases, fuel oil, steel, and other materials. Another problem with solid waste is caused by PCB, which accounts for 30-35 weight percent of waste tire materials. In this experimental investigation, PCB inclusion in construction-grade concrete was attempted. The effect of black carbon particle size on concrete was examined in the current research. The compression test, which was performed in the testing, used six different PCB particle sizes. The results showed that the strength in the 28-day compression test could be organized in an increasing fashion, with the smallest particle size (75 m) yielding the highest compressive strength. The seven-day exam is also devoid of the usual arrangement.

Keywords: Concrete, pyrolyzed carbon black (PCB), Properties of Concrete, Pyrolysis, concrete, sustainable waste management.

Introduction

One of the biggest issues with environmental solid waste in the globe is tire waste. Because it emits dangerous poisonous fumes, used tires cannot be burnt or processed in landfills. So, a number of approaches to the treatment of waste tires have been suggested (1, 2). Tire pyrolysis is regarded as the most advantageous approach out of all waste disposal options. Waste tires are converted by pyrolysis into gases, fuel oil, steel, and pyrolyzed carbon black (PCB)as a byproduct (2, 3). Steel and gas may both be purchased locally, but PCB, which makes up 30-35 weight percent of waste tire products, creates another issue with solid waste In this experimental study, an effort was made to include PCB in the concrete used in constructions. As a result, a PCB sample will be obtained from a nearby plant that pyrolyzes waste tires. It will be used directly after collection without any chemical processing. The impact of adding PCB with various particle sizes to the concrete mixture is examined in this study in relation to the compression test (1, 4). In this investigation, a typical concrete mixture is employed. One of the most widely utilized materials worldwide is cement. Due to CO_2 emissions during the cement production process, the large-scale manufacture of cement poses major environmental issues (1, 2). The environment is severely altered by CO_2 emissions, which are extremely destructive (5, 7). The production of 1 kilogram of regular cement results in the emission of about 1 kg of carbon dioxide into the environment. Since there is no replacement for cement in the building. Less damage to the environment should result from the search for a replacement or supplemental material for cement (8, 9). Using industrial by-products in a concrete mixture has allowed for the achievement of significant energy and cheap costs. Since the day concrete was discovered, pores have been seen as a significant issue (9, 10). Concrete, which is created by combining particular proportions of cement, water, and aggregates, has become a widely used artificial construction material on a global scale. Every substance has advantages and disadvantages, and concrete is no different. The fact that concrete is porous, which makes it susceptible to issues like decreased compressive strength, is one of its main weaknesses (1, 10). The use of carbon black powder as filler is one of the solutions evaluated in the study. Because carbon black powder particles are so tiny, they may readily fill the holes in concrete, reducing the number of pores that are present. Such an activity would have a lot of advantages. Better concrete density should result in less permeability, increased strength, and improved resistance to atmospheric erosion, among other advantages. Additionally, using carbon black in concrete would enable us to reuse it in a way that is less harmful to the environment, minimizing its negative effects (1, 11).

Pyrolysis, also known as thermochemical breakdown, is the process of heating waste materials, such as used tires, at extreme temperatures without oxygen in order to transform them into fuels that are high in energy. Around 500 ºC and atmospheric pressure are the conditions. Pyrolyzed carbon black is the only byproduct, making it an environmentally beneficial operation with almost no emissions or waste. The tire pyrolysis process yields a variety of primary products (1, 10):

– Gases (10 weight percent): Carbon dioxide, carbon monoxide, hydrogen, methane, ethane, and other

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hydrocarbons make up the generated gases. The employment of gases in heating is possible.

- Fuel oil (40–45 weight percent) is a useful industrial fuel for heating applications since it is strongly aromatic and has a low sulfur level.
- Steel wire (10–15 weight percent) is extremely simple to sell in the neighborhood market for the fabrication of steel.
- Carbon black powder (30-35 weight percent): This is a byproduct of the process.

A high pyrolyzed carbon black content component, also known as coke or pyrolyzed carbon black, was created as a by-product of the pyrolysis process, which was previously discussed, with yields of about 30-35 weight percent. This is 95-weight percent carbon black and more than 3-weight percent sulfur (12-14). Because the resulting carbon black contains sulfur and other heavy metals that may leach after some time after uncontrolled disposal, it might make tire pyrolysis unfavorable to the environment (15-18). Therefore, developing an effective application method for carbon black would not only make the process lucrative but also ecologically benign.

Several researchers filled concrete with a variety of materials. Jeyashree and Chitra prove the use of carbon black in concrete to have of positive effect, showing the optimum percentage of casting carbon black as filler material to be 5-8%. They demonstrate successful properties improvement, by conducting several tests. Such as; first, the flexural strength test. Second, testing concrete cubes with; Ultrasonic Pulse Velocity (UPV), Rebound hammer, and compression testing machine. Third, OCP and chloride ingress determination tests were conducted on concrete cylinders to test tensile strength (19). Padma and Pandeeswari performed a study conducted on M40-grade concrete. It was first, experimented with different concentrations of Polyethylene terephthalate (PET). However, with increasing ratios of PET, the strength of concrete decreased. Later, they added 10%, 20%, 30%, and 40% concentrations of carbon black powder, mixed with fly ash to concrete. Results showed that the addition of 30% of carbon black gave the best results, increasing the strength properties (compressive and tensile) of concrete (20).

Raza et al. studied many properties of concrete (wet and hardened); workability, bleeding, hardness, shrinkage, etc. By casting different percentages of carbon black and Calcium Sulphate, as filler and desiccant respectively, with concrete cubes and cylinders. It was demonstrated that with the addition of the right ratio percentage concrete acted more effectively. The study also proposed the manipulation of carbon and sulfate attacks (21). Kharita et al. concluded that the mechanical properties of hematite concrete improved when carbon black was added to a hematite concrete mixture of 15% of the weight of the cement. A ratio of 6% carbon black to concrete improved both the compressive strength and workability of the concrete. Due to carbon black being easily affected by heat, it was added at high temperatures in this study (22). Masadeh decided to study the ability of carbon black to reduce the corrosion rate in concrete by reducing the pores. To test this, steel bars were inserted into 5 different concrete mixes containing 0.1, 0.2, 0.3, 0.4, and 0.5 carbon black-to-cement ratios. The samples were then allowed to cure, before being immersed for 6 months in 3.5% concentration solutions of chloride. The study showed a decrease in chloride ion penetration properties, as well as corrosion rate as more carbon black was added to the concrete mix, thus providing strong evidence to support the hypothesis that carbon black can fill the pores found in concrete and reduce corrosion rate. The diameter of the particles used was around 250nm which contributed to the increase in the concrete's density (23).

In the prior paper, the impact of black carbon on concrete was investigated. The results of the investigation showed that adding 4% of PCB to concrete improved its characteristics (1). In the current research, the impact of the size of black carbon particles on concrete was investigated. Six distinct PCB particle sizes were used in the testing, which was conducted in the compression test.

Materials and Methods

This experiment uses PCB as its primary component, so any tests that are taken into consideration entail this substance. The particle size of PCB is examined at a concentration of 4% PCB because research from a previous paper indicated that this concentration is the best for enhancing concrete properties (1). The compression strength test provides the foundation for the comparison.

A number of cubes with various PCB particle sizes were cast in order to determine the ideal particle size for adding PCB to concrete. Studying the compression strength following PCB addition and comparing the findings to the control specimen (Without PCB). Two ages (7 and 28 days) were used to prepare each percent of three cubes, and the average of the specimens for each age was then calculated. Testing of specimens follows international standards for compressive strength (BS EN 12390-3&4:2019) (24)

A typical concrete contains cement (1 kilogram) (water-cement ratio (w/c) = 0.50), (2.3 kilograms), and aggregate (4.03 kilograms). Aggregate is primarily made up of aggregate type one, which weighs approximately 1.66 kilograms and has a diameter of about 18 to 25 mm; aggregate type two, which weighs approximately 0.9 kilograms and has a diameter of about 7 to 17 mm; and aggregate type three, which has a diameter of about 1-6 mm (1.46 kilogram). By adding pyrolyzed carbon black (PCB) with varying particle sizes (600 m, 300 m, 150 m, and 75 m) at 4% by weight in the amount of cement, concrete cubes with the previously mentioned ingredients and proportions were formed. Cement, water, sand, aggregates, and polycarboxylate-based high-range water-reducing superflow – G7, often referred to as superplasticizer (SP), which is acquired from Protex-A-Cote International Company (Jerusalem), are the components that make up the mix design. For all samples besides SP, a constant w/c ratio of 0.5 is utilized to improve the concrete mix's workability. Table 1 displays the mix percentage and the material composition for 1 m^3.

A local pyrolysis facility in Jenin, Palestine, supplied PCB, a by-product created during the decomposition of used tires. The PCB sample wasn't further purified before usage. Table 2 displays the PCB's proximate, elemental, and heating value analyses (10).

B300 concrete was the kind employed in this investigation. The combination was made by hand in this investigation. Sand, aggregate, and water were produced according to weight and thoroughly mixed by hand. After that, Water was added, and the mixture was stirred until smooth. After waiting for five minutes, the cement and water were combined for around three minutes. Carbon black was then added and blended for an additional three minutes.

The compression test was carried out following the preparation of the concrete samples and material mixing. The concrete cubes were immersed in water for 7 and 28 days during the experiments, which were conducted in a water bath. Wait seven days to obtain the results of the initial specimens, which include (60–70%) of the overall strength, and 28 days to obtain the findings of the final specimens, which contain 100% strength.

Table (1): Mix Proportions of concrete mixes.

Cement	Water	Sand	Aggregates	PCB	SP
(kg/m^3)	(kg/m^3)	(kg/m^3)	(kg/m^3)	(kg/m^3)	(kg/m^3)
332.7	166.4	765.2	1340.8	13.3	7.1

To determine the compression strength, the concrete samples were put in compression testing equipment.

effects might involve cancer, infertility, allergy, antibiotic resistance, and endocrine disorders (19, 23).

Results and Discussion

The concrete cubes were placed in the compression testing apparatus as seen in Figure 1 to estimate the specimens' compression strength. The load was then added steadily until the specimen broke. It was noted at what load the specimen failed. The Compression Strength Testing Machine is seen in Figure 1.

The efficacy of the PCB on the concrete was assessed using the test results after the laboratory experiments had been planned and carried out. Concrete with various PCB particle sizes was compared to blank concrete (concrete with 0% PCB).

After preparing three cubes of each particle size with different ages (7 and 28 days), the average of the specimens for each age was obtained, and a PCB particle size of (random, 600 m, 300 m, 150 m, 75 m) at 4% by weight in the amount of cement was advised to achieve the best strength.

Tables 3 and 4 show the findings for the average compression strength test after 7 and 28 days, respectively.

Table (2): Proximate, elemental, and heating value analysis for the PCB [10].

Element	PCB(% wt)
C[1] (%)	95.42 ± 0.16
H[1] (%)	0.77 ± 0.20
N[1] (%)	0.22 ± 0.07
S[1] (%)	3.29 ± 0.09
Cl[1] (%)	0.19 ± 0.01
O[1] (%)	0.12 ± 0.07
Ash	16.5 5± 0.34
Moisture	1.16 ± 0.14
Volatile matter (%)	2.50 ± 0.74
HHV (MJ/kg)	28.70 ± 0.18

[1] Results on a dry basis with ash-free.

Figure (1): Compression testing machine.

Table (3): Average compression strength test results after 7 days.

PCB ratio & Particle Size	Weight (gm)	Density (gm/cm^3)	Compression test (MPa)
0%	2379.0	2.379	21.2
4% Random	2285.6	2.285	29.03
4% at 600 µm	2241.6	2.241	29.7
4% at 300 µm	2256.6	2.256	23.6
4% at 150 µm	2296.3	2.296	24.6
4% at 75 µm	2332	2.332	26.3

Table (4): Average compression strength test results after 28 days.

PCB ratio & Particle Size	Weight (gm)	Density (gm/cm^3)	Compression test (MPa)
0%	2160.6	2.16	29.5
4% Random	2177.6	2.177	38.26
4% at 600 µm	2147	2.147	35.4
4% at 300 µm	2165	2.165	37.6
4% at 150 µm	2179	2.179	40.5
4% at 75 µm	2228	2.228	42.4

Figures 2 and 3 illustrate the impact of adding PCB to the concrete mixture.

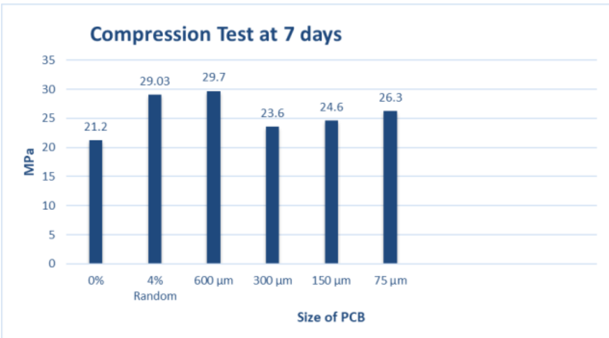

Figure (2): Average compression strength test results after 7 days.

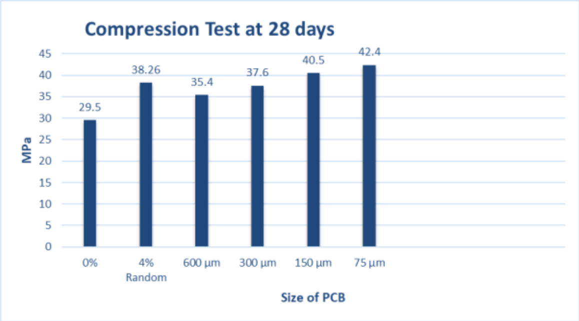

Figure (3): Average compression strength test results after 28 days.

According to Table 1, Table 2, Figure 1, and Figure 2, the compression strength for the concrete specimen with 4% percentage and PCB size of a random particle, 600 m, 300 m, 150 m, and 75 m is higher than that for the blank concrete specimen. This demonstrates how PCB makes the concrete mix more compressively strong. Additionally, it may be said that the greater the concrete's compressive strength is, the smaller the particle size is. This is because smaller particles can fill in the pores in concrete, making it stronger and more compressive.

It is clear that the smallest particle size (75 µm) has given the best compression strength at the 28-day test.

PCB should produce fewer pores and increase the concrete mix's adherence. After 28 days, the PCB particle size affects the compressive strength. The connection between the PCB particles and the concrete is not very strong after 7 days.

Conclusion

In this research, the impact of adding PCB to concrete that was produced locally at a factory that pyrolyzed waste tires were examined. Since the cement is the only material available for building. There would be less of an impact on the environment if PCB was used as an alternative or supplemental material for cement. It's been feasible to accomplish Low cost and significant energy savings when utilizing PCB in a concrete mixture.

The use of pyrolyzed carbon black (PCB) in a concrete mixture resulted in greater concrete compression strength, according to the prior findings. When a PCB with a 4 wt % and 75 m particle size is added, the compression strength is at its highest. Moreover, PCB ought to improve the adhesion of the concrete mix and result in fewer pores. The size of PCB particles has an impact on compressive strength after 28 days. After 7 days, the interaction between PCB particles and concrete is incomplete and has little impact.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The raw data required to reproduce these findings are available in the body and illustrations of this manuscript.

Author's contribution

The authors confirm contribution to the paper as follows: study conception and design: Osayd Abdulfattah, Ramez Abdallah, theoretical calculations and modeling: Osayd Abdulfattah, Ramez Abdallah; data analysis and validation, Osayd Abdulfattah, Ramez Abdallah. draft manuscript preparation: Osayd Abdulfattah, Ramez Abdallah. All authors reviewed the results and approved the final version of the manuscript.

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Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this article

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